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TRANSACTIONS

OF THE

ILLINOIS STATE ACADEMY OF SCIENCE

VOLUME 50 1957

Fiftieth Annual Meeting

Normal, Illinois

May, 1957

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14

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CONTENTS

ADDRESSES

Page

HUNTER, JOAN, Let the Chips Fall Where They May 7

PROGRAM

Papers Presented at the 50th Annual Meeting 17

AQUATIC BIOLOGY

LEWIS, WILLIAM M., The Fish Population of a Spring-fed Stream System in Southern Illinois 23

WARREN, GEORGE P., JR., Fishing Pressure and Fishing Success at Argyle Lake, McDonough County, Illinois, as Indicated by Creel Census 30

LEWIS, WILLIAM M., and EDWARD CHARLES, Flotation of Fishes Following Stunning by Electrical Shock 38

STARRETT, WILLIAM C., Fishery Values of a Restored Illinois River Bottomland Lake 41

PARSONS, JOHN DAVID, Literature Pertaining to Formation of Acid-mine Wastes and Their Effects on the Chemistry and Fauna of Streams 49

PALOUMPIS, ANDREAS A., The Effects of Drought Conditions on the Fish and Bottom Organisms of Two Small Oxbow Ponds 60

BOTANY

MEADOWS, EDNA L., University of Illinois Herbarium, Its History and Development Since 1868 65

KAEISER, MARGARET, and STANLEY E. HARRIS, JR., Plant Fossils from Mankato Terrace Along Hutchins Creek, Union County, Illinois 68

ARATA, ANDREW A., Notes on the Ecology of American Lotus in Southern Illinois 71

JOKELA, J. J., and RALPH W. LORENZ, Growth and Yield of Sinnissippi Forest Stands 76

FELL, EGBERT W., and GEORGE B. FELL, The Ravine Flora of Winnebago County, Illinois 83

MCKINNEY, L. L., and V. L. JOHNSEN, Modification of Zein by Deamidation 90

CHEMISTRY

GERSHBEIN, LEON L., and BOGUSLAW K. KROTOSZYNSKI, Absorption of Oxygen by Blood Plasma Fractions in Alkaline Media 96

SHER, BEN C., The Effect of Isoniazid on the Immunity Produced by Vaccination of Guinea Pigs with BCG 99

GYLYS, J. A., and C. D. PROCTOR, Study of a Blood Polarographic Change Associated with Walker Tumor Growth 106

WEATHERBEE, CARL, WILLIAM BOOMER, CURTIS O. BERREY, and HOWARD K. S. LAU, Stearic Hindrance Effects of the Tertiary Butyl Radical in Some Mannich Condensations 114

YUSKEN, JOHN W., and ELWOOD F. REBER, Effects of Feeding Baby Pigs a Diet Deficient in Sodium 118

GEOGRAPHY

ROBERTS, WYNDHAM J., Saving Water in Reservoirs 124

HAMMING, EDWARD, Teaching of Conservation of Natural Resources in Illinois Colleges and Universities: A Re-Appraisal 130

MCINTOSH, CHARLES BARRON, Forecasting Explosion conditions in Coal Mines ... 133

WINTERS, HAROLD A., The Changing Petroleum Industry of Western Europe 144

PETTERSON, DONALD R., Kenya, East Africa: An Aspect of Population Geography 152

CARMIN, ROBERT L., A Land-Use Map from Census Data—Parana, Brazil, as an Example 159

STROEBEL, WILLIAM, Large Scale Commercial Beef Cattle Feeding in Northern Illinois 163

GEOLOGY

Page

BUHLE, MERLYN B., Uses and Limitations of Electrical Prospecting for Water Supplies 167
WHITING, L. L., and MARGARET O. OROS, Electric-Log Cross-Sections of the Silurian-Devonian Formations of a Part of Central Illinois 172
PARIZEK, RICHARD R., Source and Occurrence of Brines for Waterflooding in Illinois 180
DUBAR, JULES R., Age and Stratigraphic Relationship of the Caloosahatchee Marl of Florida 187
DROSTE, JOHN B., and ROBERT W. DOEHLER, Clay Mineral Composition of Calcareous Till in Northwestern Pennsylvania 194
DESBOROUGH, GEORGE A., Faulting in the Pomona Area, Jackson County, Illinois.. 199
HARRIS, STANLEY E., JR., Valley-Side Erosion in Southern Illinois..... 205

PHYSICS

ARVIN, MARTIN J., and ROBERT C. ETHERTON, Modern Dielectric Theory Applied to Polymethyldisiloxane Molecules 209
LANDAHL, H. D., and T. N. TRACEWELL, An Investigation of Cigarette Smoke as an Aerosol with Special Reference to Retention in Lungs in Human Subjects.. 213

SCIENCE EDUCATION, PSYCHOLOGY, AND SOCIAL SCIENCE

DUBINS, M. IRA, Subject Matter Trends in Science in Elementary Schools as Shown by Courses of Study 221
OLIVIA, SISTER MARY, Challenge Accepted!.. 227

ZOOLOGY

HOFFMEISTER, DONALD F., and JOHN R. WINKELMANN, The Os Clitoridis in the Badger, Taxidea taxus 233
PARAMALEE, PAUL W., Vertebrate Remains from the Cahokia Site, Illinois..... 235
FOOTE, CHARLES L., and FLORENCE M. FOOTE, Maintenance of Gonads of Frog Larvae in Organ Cultures 243
KLIMSTRA, W. D., and E. L. CORDER, Food of the Cottontail in Southern Illinois.. 247
STAINS, HOWARD J., A Clue to Spring Molt in Raccoons as Revealed in Analysis of Scats 257
BENNETT, ESTHER V., Nesting Birds of the Shoreline and Islands of Crab Orchard Lake, Illinois 259
RIEGEL, GARLAND T., The Range of Zorotypus hubbardi with an Illinois Record (Insecta: Zoraptera) 265
KRUIDENIER, FRANCIS J., and KRISHNA N. MEHRA, Mucosubstances in Plagiorchoid and Monostomate Cercariae (Trematoda: Digenea)..... 267
STANNARD, LEWIS J., JR., The First Records of Boreus (Boreidae, Mecoptera) in Illinois 279
SANDERSON, MILTON W., North American Stenus of the advenus Complex Including a New Species from Illinois (Coleoptera: Staphylinidae) 281
MADISON, KENNETH M., Fossil Protozoans from the Keewatin Sediments..... 287
LEVINE, NORMAN D., VIRGINIA IVENS, and FRANCIS J., KRUIDENIER, New Species of Eimeria (Protozoa: Eimeriidae) from Mexican Rodents..... 291
DOWNEY, JOHN C., Observations and New Records of Hymenopteran Parasites of Lycaenid Eggs (Lepidoptera) 299

COLLEGIATE

CORKUM, K. C., R. RINGHOUSE, and S. ROESCH, A Parasite of the Swim Bladder of Black Catfish 301
LOIZZI, ROBERT F., A More Efficient Mold for Plastic Embedding..... 303
FREY, D., and D. MITCHELL, Electrolysis of Aqueous ∂-Cyclohexylbutyrate..... 305

ACADEMY BUSINESS

Secretary's Report for 1956-1957 308
Constitution and By-Laws of the Illinois State Academy of Science..... 315

PRESIDENTIAL ADDRESS

LET THE CHIPS FALL WHERE THEY MAY

JOAN HUNTER

Edwardsville High School, Edwardsville

JOAN HUNTER, *President,* 1956-1957

One of the most important jobs of the teacher is to inspire his students. He must help them to see themselves and their work as a part of a whole picture, to develop a relative sense of values, to develop a sense of humor, to find the area of work for which they are best suited, and to help them develop the necessary foundation skills with which to do their best work. But above all, the student must be so inspired that he becomes willing to spend time and effort working to develop skills necessary to do his work well, not only in the teacher's field of interest but in other fields in which he is involved.

Because my primary interests are in the biological sciences I should like to apply this viewpoint more directly to the teaching of biology.

The longer I teach the more I am convinced that the job of a high-school biology teacher is not only to cultivate a scientist but to develop a person. This does not imply that we should not seek and encourage those with ability and interest to become scientists. It does mean that the boy or girl without this particular inclination should learn to appreciate the work of the scientist and should learn to apply scientific methods to his daily problems. We must help him to see that no matter which occupation he chooses, biology can enrich his life. Because we have potential scientists in our classes, we must teach biology as though all our students were planning a career in science. But since we know that most of our students are not going to be scientists, we must also teach biology as a cultural course.

It is not enough to sit back and say that Mary Jane cannot do very well because of low ability. We must see to it that all the Mary Janes in a class get the most of which they are capable. This is also true of the students of average ability; it isn't enough that they do passing work. They must be encouraged to find their level of ability—not just get along. They should be developing interests and whetting their appetites for knowledge. The above-average students must be encouraged to broaden their horizons, to develop their originality, and to go beyond the work of the class.

This then is the challenge. All students must be inspired to work to their full capacity and to find joy in learning.

Most members of the high-school biology class are sophomores and my remarks will be made with them in mind. What is a high-school sophomore? To me, he is a livewire of 14 or 15 years all wired for sound, who at times thinks the world is his oyster now that he is no longer a freshman and who at other times is very unsure of himself and wants the voiced approbation and support of his parents or teacher. He is a bundle of curiosity and uses the words "how", "why" and "what if" more often than the general populace. He wants to know what is the "biggest", the "smallest", the "fastest", and the "best" of everything. He comes to biology with the idea that the book is always right and leans heavily on it for proof. He is a serious-minded person with high hopes and ambitions. He is a dreamer and a sentimentalist, but he is also very practical.

He wants to take part in everything — sports, music programs, plays, dancing and dating, church work, and academic work. He is a great competitor, downhearted at criticism but willing to try again.

A sophomore is one who wants to please his teachers, although he will try out each of them to see how much he can "get by with". He wants to be liked and will usually work toward gaining the personal interest of his teachers. If he knows that he has their consideration, he will aspire to many things—except putting away equipment he has used to carry on his own investigations! After numerous reminders he may even learn to do this.

But there are many exceptions to this description of a sophomore. There is the boy who has not developed the emotional maturity of most

other sophomores and finds it more fun to plague his teachers than to get his work done. There is the girl whose emotional problems drown her other interests. There are boys and girls who have been promoted socially but have not developed the necessary skills in writing and reading. There are the lonely boys or girls. And, of course, there are the boys and girls who are not capable of doing very much academically. These too, must be taught! And inspired!

Biology teachers have an advantageous position for doing just that. There is already a natural curiosity about living things. Maintaining this interest in the face of the hard work involved in learning new words, facts, and methods is a different story. Relating biology to other fields of study helps maintain this interest and is one method of inspiring students to put a value on all learning.

Most high-school students regard each subject as an entity with no relationship to other subjects. This is not necessarily a fault; rather, it is a natural condition of their years. It is up to the teachers to help the students relate facts learned in one course to problems and ideas arising in another. The teacher must help them gain an appreciation of knowledge so that they may make that knowledge a part of themselves rather than a collection of facts to be laid aside once the final examination is passed.

It is the purpose of this paper to present some examples of these relationships. During one year a teacher is not likely to use all of these illustrations, but they may be used as a storehouse to be brought out when needed. Relating biology to other areas builds a bond between student and teacher and helps the student see a teacher as a person who has other interests besides the one with which the student usually associates him. This personal feeling encourages students to achieve.

Some of these illustrations may better be used elsewhere, as in science club activities, after-class discussions, or in a camping situation.

Care must be taken to use these illustrations judiciously. Otherwise, they may turn out to be instances of the tail wagging the dog. The fact remains that one must teach biological facts and scientific methods first and best. These illustrations are only embellishments for the basic material in most cases. Perhaps this paper should have been entitled "Incidental Teaching in Biology". However, I prefer to think that we can "hew to the line" by teaching the basic concepts of botany and zoology and "let the chips fall where they may" by bringing in incidental materials when and if appropriate.

Biology teachers, no less than other teachers, must encourage good grammar, spelling and composition. It is apparent that many students regard grammar and spelling as subjects rather than as tools. They treat punctuation marks as though they were butterflies and let them alight anywhere. Some have a defeatist attitude toward spelling. They say, "they never could spell", "their mothers had trouble with spelling". They are slow to adopt new forms of speech in everyday conversations. Only as teachers in other areas insist that students use these tools will their use become habit.

Projecting written papers on a screen and subjecting them to class criticism and suggestion is one of the best methods I have used for improving written work. Compliments on success also encourage continued improvement.

Since the ability to tell others your thoughts is important and since there are so many things in biology that students want to tell, cultivation of the ability to speak before a group has a natural place in a biology class.

As far as the spoken grammar is concerned, one has the problem of deciding just how many interruptions a recitation may have without losing its biological value. Certainly, gross errors, such as "he don't", "I seen", and "it ain't" should not go by without comment. I suggest that students organize for better speech. They use co-operative efforts for learning to dance, to play cards, to sing. Why not for better grammar?

Students with spelling and vocabulary difficulties need help and encouragement, rather than constant critcism. Stress should first be put on the importance of learning those words which will be in repeated use instead of on words which are little used. Students with real spelling difficulties have trouble with college preparatory biology because of the many new words involved. Since students with the worst difficulties do not usually go to college, a course designed with fewer scientific terms can satisfy the cultural value of biology for these non-collegiate students. All learning must not be forfeited because a student does not have the ability to spell!

Because it is easier to say things in biology when one knows the proper term, even if the word is a long one, students learn to add to their vocabularies and because so many biological terms are spelled as they sound, students lose some of their fear of long words which they have hitherto avoided. They can be made to realize the fact that longer words are combinations of syllables which actually express a thought, as Echinodermata which means "having a spiny skin" or "a skin like a hedgehog". They can also be taught that it takes just as long to say "Echinodermata" as it does to say "I am going to town" and that the pronunciation of each syllable is as important as the pronunciation of each word in a sentence. Thus students gain confidence and improve in the use of words.

This brings up another "chip" that flies frequently in biology. That is, the derivation of words. There is no better place to convince students that they can make good use of languages, especially Latin and Greek. Vocabulary growth is rapid, once the students grasp the idea that the same syllable from Latin or Greek is used over and over in combinations with other syllables to form English words. Even some of the slower students become fascinated with the organization of words and enjoy building words to use in biology.

The first approach to this can be made in the fall when students are formally introduced to the "ologies" —biology, zoology, herpetology, ornithology, and so on.

The unit on insects is not only one of high interest with which to begin

the course but so many basic things can be taught during its study.An early lesson in observation, note-taking, and classification is a necessary part of this unit. This also offers a good opportunity for word study. After collecting a number of insects one can observe them and find characteristics common to all. Then using the characteristic of jointed appendages, the name of the phylum can be derived. Usually, someone in the class will be able to supply the syllable ''ped'' meaning foot. Then, upon being asked the name of the disease affecting the joints, they produce the word ''arthritis''. From these two words the word ''Arthropoda'' is formed

After the common characteristics are discovered, students are asked to separate the insects into groups according to the kinds of wings which they have. After discussing this grouping, the scientific names of the orders are developed. Students are told that ''ptera'' is derived from a Greek word meaning ''wing'' and that we need to add a prefix describing the wing in order to have the scientific name of the group. Some of these they can get when other words with which they are familiar are brought to mind. Orthoptera is associated with orthodontist, Hemiptera with hemisphere, Neuroptera with neurology, etc. It becomes a game and the students are all attention. It doesn't take them long to learn names this way, and it helps the students correlate tool subjects with working subjects. Sometimes this is not as simple as it sounds. In an attempt to get the meaning of the syllable ''mono'' I once asked a girl what monogamy was. She said she thought it was a kind of wood!

Many fine works of literature necessitate biological interpretation. Quite often the problem is one of ecology as we find in Henry W. Longfellow's ''Evangeline''. Maps and pictures taken in Acadia show the student the ecology and conservation practice of this land when the following description is read.

"In the Acadian land, on the shores of the Basin of Minas, Distant, secluded, still the little village of Grand Pre Lay in the fruitful valley. Vast meadows stretched to the eastward,
Giving the village its name, and pasture to flocks without number.
Dikes, that the hands of the farmers had raised with labour incessant
Shut out the turbulent tide; but at stated seasons the flood-gates
Opened, and welcomed the sea to wander at will o'er the meadows
West and south there were fields of flax, and orchards and cornfields
Spreading afar and unfenced o'er the plain; and away to the northward
Blomidon rose, and the forests old, and aloft on the mountains
Sea-fogs pitched their tents and mists from the mighty Atlantic
Looked on the happy valley, but ne'er from their station descended.
There in the midst of its farms, reposed the Acadian village."

Sometimes a quotation placed upon the blackboard can be the lead for a discussion. For example, this one from Ralph Waldo Emerson's essay on ''Nature'' has led to a discussion on conservation. ''Only as far as the masters of the world have called in nature to their aid, can they reach the height of magnificence.''

Without involving religion, many Biblical references can be explained in biology. The''fiery serpent'' mentioned by Moses was probably the guinea worm, a parasitic worm of tropical Africa, Arabia, and India.

As a child, it always seemed an ignominy to me that while Christ was on the Cross and asked for a

drink of water the soldiers not only gave him vinegar to drink but offered it to Him on a sponge. Years later I found that the sponge was a common drinking utensil of the Roman soldier.

Biologically, the whale being a plankton eater could not swallow a man. When this surprising fact is announced, the students immediately ask about Jonah.

The manna of the Israelites is a lichen which grows in Northern Africa and western Asia. A strong wind sometimes loosens the lichen and pieces of it are blown about. When ground it makes a fine flour for bread.

Mathematics seems to be very difficult for a large number of students. Any applications of this subject would certainly make students realize the importance of studying it. The arrangement of buds on a branch, the spirals on the shell of a snail, and the spirals of an unfolding fern frond are good examples of the golden mean. Checking the speed of a bird by using trigonometry and the placing of biological data obtained by experimentation into graphs and tables are other uses of mathematics. Many mathematical terms such as symmetry, radial, tangential, and concentric are used directly in biology. The way a student's eyes light with previous knowledge when mention is made of tangential cuts of wood is one of the pleasurable moments of teaching.

Many students enjoy studying history. The development of the civilizations of the world has depended upon the biological resources of an area. Primitive man roamed the forests subsisting on the plants and animals which he found there. His food consisted of small game, fish, fleshy fruits, nuts and herbs. What little clothing and shelter he had were skins, plaited grasses, and bark. He used shells and ivory for ornamenting them. As man domesticated animals he took up herding. Later he learned the function of a seed and began to farm. The more kinds of crops he domesticated the more kinds of animals he could domesticate and put to his use.

The changes in the centers of civilization in more modern times are directly connected with conservation of natural resources, particularly those of the soil. China, at one time an important center of culture, lost its place when its overused lands failed to support its people. In an attempt to overcome the low crop production, human wastes are used on the fields and thus parasitic worms are spread among the people who walk barefoot in the rice paddies planting their rice. Disease and lack of proper food are thus contributing to China's economic status.

In Greece and Italy the same overuse of land can be witnessed. Will the United States take the same road? Students need to be made aware of the long-range effects of poor conservation.

The settlement of various parts of the world was brought about partly by the differences in the flora and fauna of certain regions. Our own country was discovered in the European's search for spices which he could not grow at home. Canada was opened up by the presence of large quantities of codfish. The search for furs helped to open up the West.

The paths taken by animals to salt

licks were the origins of many important roads built upon the advent of the white men. Even some of our present highways follow these old trails.

The course of history might have been changed if it had not been for the malaria-carrying mosquito found in the Panama Canal Zone and for General Gorgas and his experimental studies of the disease.

History is also found in the study of genetics. An example of this is the story of hemophilia in the royal families of Europe. Queen Victoria, who apparently was a mutant for the trait, introduced the disease into the royal family. By marriage it spread to the Russian and Spanish royal families. A granddaughter, who was also a carrier, married Nicholas II, Czar of the Russians and became the mother of a hemophilic son. The mad monk, Rasputin, was called in to cure the child and thus worked himself into the most powerful position in Russia and probably touched off the Russian Revolution of 1917. A daughter of Queen Victoria married Alfonso XIII of Spain. They had five sons, four of whom were hemophiliacs. This probably played an important part in the overthrow of the Spanish throne.

An understanding and appreciation of the peoples of the world can be furthered by introducing biology students to some of the different eating habits of people whose differences exist because of their environment. Students squirm when told that insect eggs and larvae are considered delicacies in some parts of the world and that seaweed, jellyfish, squid, and octopus are eaten by many people who live near the sea. The story of the American visiting in the Orient clearly illustrates the fact that although people's customs differ from our own they are not necessarily more peculiar than our own. This American asked a Chinaman, "How does it happen that you put food beside your people when you bury them? They can't eat after they are dead." The reply came quickly, "No, but dead people can't smell flowers either."

Appreciation of people can also be brought about by the study of men of science. The variety of nationalities involved shows that no one nation has a monopoly on intelligence. The importance of international exchange of scientific information can also be stressed.

Students must realize that knowledge grows upon knowledge and discoveries do not usually come overnight. The contributions of ancient peoples cannot be overlooked. Three thousand years ago the Hindus used *Rauwolfia* to treat fever and snakebite. It was later used to treat insanity and the people of India even gave it in small doses to their children to put them to sleep. Ghandi used it during his periods of passive resistance. Medical men of more enlightened countries are just beginning to appreciate the knowledge of these earlier people and have begun to study *Rauwolfia* and other herb medicines.

Students must not feel that all the exciting discoveries were made before they were born. Let them compare the romance of the conquest of polio with that of smallpox. The two and in results which may eventually followed, in prejudices to overcome, are almost identical in procedures

be the same. The part today's students are playing in the fight against polio is just as romantic as the part played by the people of Edward Jenner's day. Our teenagers, too, are a part of history although their names will not appear in print!

There is much psychology which can be taught through through biology. Using insects as an example, one can show how the actions of a few can influence the reputation of the group. This applies directly to the actions of high-school students who are often under fire by some adults.

The degeneration of tapeworms because of their parasitic habits can be likened to the parasitic habits of some human beings.

Theoretically, the study of courtship behavior among birds can be compared to the students' own reactions. A brief discussion helps them to view some of their emotions and awkward reactions in a somewhat objective and humorous light for a greater understanding of themselves. The mature, biological approach to the problem helps guide them toward emotional maturity.

The need for making decisions and for telling the truth is important for good mental health. Both are important parts of any science course. The need to develop self-confidence is important. To timid students I quote James B. Conant, "Behold the turtle. He makes progress only when he sticks his neck out."

Music and art make use of biological materials. Without tools, natural objects became important in making early musical instruments. One of the earliest was made of a tortoise shell with four strings. Another was a gourd with bamboo tubes of different lengths. Reeds of varying lengths made the pipes of Pan which, according to legend, he called a syrinx after his lost sweetheart. Today we call the voice box of a bird a syrinx.

Students are interested in the many materials used in making musical instruments today and in discovering why certain materials are preferred to others. For instance, they are interested in finding out why horse hairs are used in violin bows and why spruce wood is preferred to oak for making sounding boards for pianos.

Biology played a part in the artistic appearance of early instruments for many of them were shaped like animals. The early zither, for example, was shaped like a crocodile.

Natural music is found in the trees as the wind passes through the leaves. Landscape architects sometimes express the idea that evergreen plantings give a more relaxing effect than do the hardwoods with their rustling leaves.

In such musical compositions as "Autumn Leaves" and "Flight of the Bumblebee" natural sounds have been imaginatively put into musical form. I have never heard an orchestral arrangement of the frogs in a pond. Perhaps someday one of the music majors who has listened to the recordings of frogs' voices in a biology class will be inspired to put the piccolo-voices of the spring peepers, the bass viol-voices of the bullfrogs, and the brass-voices of the leopard frogs into a musical composition complete with all the antiphonal effects one hears at a frog pond.

When students have difficulty

remembering the scientific names of the animal phyla I often wonder why someone doesn't set the list to music. Teenagers often learn monosyllabic, nonsensical sounds when they are set to music. Why not scientific syllables?

One of my students a few years ago had difficulty remembering the relative positions of the xylem and the phloem tissues in stems. One day she volunteered the information that she now sang "phloem on the outside; xylem on the inside" instead of the popular song version "laughing on the outside; crying on the inside."

To some this may seem trite, but I believe flights of fancy keep the students' imaginations alive and unfettered until they mature and can be put to practical use in a creative way.

Because plants and animals were, and are, so closely associated with the lives of people, many designs of plants and animals are found in baskets, pottery, woven mats and jewelry. From some of this natural history, art knowledge of ancient peoples has been obtained, as witness the hunting scenes found in caves, the animals woven into the Eskimo baskets, and the plants of the Incas painted on their pottery.

The artistic use of natural materials such as the use of plants and animals in making dyes is of interest. Birch baskets embroidered with porcupine quills or trimmed with sweet grass elicit admiration and curiosity.

Perhaps the rarest and most unusual natural object used as an art medium is the web of a spider or caterpillar. Paintings were done on these webs in a Tyrolean valley more than 200 years ago. The thicker, fall web was cleaned and stretched across a piece of cardboard and was sometimes sized with milk diluted in water. A miniature technique was used and parts of the web were left unpainted to show the unusual fabric. As far as I know this is a lost art. Could an art student be inspired through biology to revive it?

The relation of biology to other fields might be extended to the use of biological objects as symbols in the religions of the world, in furniture and cloth designs, popular expressions, stamp and coin collections, and no doubt, in many others.

For my final point I should like to say that even the comics and cartoons come to biology class. Occasionally I have found cartoons which illustrate some biological principle. These I keep and often use on an examination with the instruction "explain what is wrong" or the question "what biological principle is involved here?" For example, I have one showing a little boy looking at a row of beans which have just sprouted. His comment is, "Look, Mommy, all the beans have come unplanted."

I have one showing Nancy, of the comic strip of the same name, tying the long ropes of a swing to the low branch of a very small sapling. An empty bottle of fertilizer lies on the ground beside her. My question is "Why is Nancy going to be disappointed?"

A cartoon which I enjoy using on the bulletin board just for the humor involved is a picture of two caterpillars crawling along the ground. Overhead is a butterfly. The legend shows one caterpillar

saying to the other, "You won't catch me up in one of those things".

In all the areas touched upon in this paper many more examples could be given. I have related a few and have tried to show that a biology class can offer inspiration to all students whether they are interested in music, literature, art, history, semantics, religion, sociology, psychology, or science. It can be a place to whet the appetites for knowledge and to keep the creative imaginations alive, if teachers will take the time to let a few chips fall where they may while they hew to the line of basic scientific training.

PROGRAM FOR THE 50th ANNUAL MEETING
PAPERS PRESENTED

AQUATIC BIOLOGY

ROBERT J, SCHOFFMAN, *Chairman*
Spalding Institute, Peoria

*Fish Population of a Spring-fed Stream System in Southern Illinois. William M. Lewis, Southern Illinois University, Carbondale.

*Fishing Pressure and Fishing Success in Argyle Lake, McDonough County, Illinois, as Indicated by Creel Census. George P. Warren, Jr., Blue Mound High School, Blue Mound.

Breeding Habits of Illinois Fishes. Hurst H. Shoemaker, University of Illinois, Urbana.

*Flotation of Fishes Following Stunning by Electrical Shock. William M. Lewis and Edward Charles, Southern Illinois University, Carbondale.

Superphosphate as a Pond Fertilizer. Donald F. Hansen, Illinois Natural History Survey, Urbana.

A Creel Census and Fish Population Study in a Small, Central Illinois Stream. Richard E. Bass, Illinois Department of Conservation, and R. Weldon Larimore, Illinois Natural History Survey, Urbana.

*Fishery Values of a Restored Illinois River Bottomland Lake. William C. Starrett, Illinois Natural History Survey, Havana.

An Experiment in the Baiting and Control of Carp. Homer Buck and Maurice Whitacre, Illinois Natural History Survey Laboratory, Dundee.

Food Conversion in Some Hybrid Sunfishes. William F. Childers, Illinois Natural History Survey, Urbana.

Effect of Drouth Conditions on a Stream Population. R. Weldon Larimore and William F. Childers, Illinois Natural History Survey, Urbana.

Age and Rate of Growth of the Carp in Reelfoot Lake, Tennessee, for 1941 and 1956. Robert J. Schoffman, Spalding Institute, Peoria.

*Literature Pertaining to Formation of Acid Mine Wastes and Their Effects on the Chemistry and Fauna of Streams. John David Parsons, Western Illinois University, Macomb. By title only.

ARCHAEOLOGY AND ANTHROPOLOGY

WILLIAM H. FARLEY, *Chairman*
Harrisburg, Illinois

Pathological Conditions in Prehistoric Indian Skulls. James R. Reed, Quincy.

Prehistoric Stone Artifacts Illustrated by Color Slides. Gray LaDassor, St. Louis, Missouri.

Prehistoric Culture of Western Illinois. Claude U. Stone, Peoria, and Don Dickson, Lewistown.

The American Indian and Abraham Lincoln. C. C. Burford, Urbana.

Florida's Present Day Seminole Indian. Irvin Peithmann, Carbondale.

* Published in this volume.

BOTANY

JEAN M. VOEGELI, *Chairman*
Rockford College, Rockford

*University of Illinois Herbarium, Its History and Development since 1868. Edna L. Meadows, Stephen Decatur High School, Decatur.

A Statistical Analysis of the Flora of Illinois. G. Neville Jones, University of Illinois, Urbana.

*Plant Fossils from Mankato Terrace along Hutchins Creek, Union County, Illinois. Margaret Kaeiser and Stanley E. Harris, Jr., Southern Illinois University, Carbondale.

*Notes on the Ecology of American Lotus, Nelumbo lutea, (Nelumbonaceae), in Southern Illinois. Andrew A. Arata, Southern Illinois University, Carbondale.

*Growth and Yield of Sinnissippi Forest Stands. Jalmer J. Jokela, University of Illinois, Urbana.

Growth of Basswood under Several Substrate and Nutrient Conditions. William Clark Ashby, University of Chicago, Chicago.

The Influence of Reproductive Development on the Absorption of Water by Xanthium Plants. Wayne J. McIlrath and Robert J. Kuster, University of Chicago, Chicago.

Germination of Seed and Temperature Factor in Triploid Citrullus vulgaris. Z. Obara and O. Eigsti, Chicago Teachers College, Chicago.

Organography and Vascular Anatomy of the Flower in Four Species of Gaylussacia. Barbara F. Palser, University of Chicago, Chicago.

Colchicine Induced Chromosome Breakage in Collinsia heterophylla Buist. Joventino D. Soriano, University of Chicago, Chicago.

Elm Tree Disease: Diagnosis and a New Treatment. Howard D. Salins, Flax Institute of America, Chicago.

*The Ravine Flora of Winnebago County, Illinois. Egbert W. Fell, Rockford College, Rockford, and George B. Fell, Nature Conservancy, Washington, D. C. By title only.

Development of the Sympodial Axis in Inflorescences of Myosotis laxa and Mertensia virginica. Paul V. Prior, Texas Technological College, Lubbock, Texas. By title only.

CHEMISTRY

Section A

W. F. BAILEY, *Chairman*
MacMurray College, Jacksonville

Quick Approximate Titration-Curve Calculations. G. W. Thiessen, Monmouth College, Monmouth.

Chemical Quality of Surface Waters in Illinois. T. E. Larson and B. O. Larson, Illinois State Water Survey, Urbana.

Some Observations Concerning Education in Science. Carl Weatherbee, Millikin University, Decatur.

Dioxo-axazines. Nicodemus E. Boyer, Hooker Electro-Chemical Company, Niagara Falls, New York.

Experimental Studies on Catalase Inhibition by 3-Amino-1, 2, 4-Triazola. Frank O. Green, Wheaton College, Wheaton.

*Modification of Zein by Deamidation. L. L. McKinney and V. L. Johnsen, Northern Regional Research Laboratory, Peoria.

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Section B

HARRIS E. PHIPPS, *Presiding*
Eastern Illinois University, Charleston

A Method for Determination of Adenosinetriphosphate in Tissues. John Rebar, Jr., Blanche Tigerman Rebar, and Charles D. Proctor, Loyola University, Chicago.

*Absorption of Oxygen by Blood Plasma Fractions in Alkaline Media. Leon L. Gershbein and Boguslaw K. Frotoszunski, Illinois Institute of Technology, Chicago.

Hemato-Encephalic Exchange as a Function of Age. JoAnn C. Peterson and Williamina A. Hinwich, Galesburg State Research Hospital, Galesburg.

*The Effect of Isoniazid on GCB Vaccination of Guinea Pigs. Ben C. Sher, Municipal Tuberculosis Sanitorium, Chicago.

*Study of a Blood Polarographic Change Associated with Walker Tumor Growth. J. A. Gylys and Charles D. Proctor, Loyola University, Chicago.

*Stearic Hindrance Effects of the Tertiary-butyl Radical in Some Mannich Condensations. Carl Weatherbee, Howard K. S. Lau, and William Boomer, Millikin University, Decatur.

*The Effects of Feeding a Diet Deficient in Sodium to Baby Pigs. John W. Yusken and Elwood F. Reber, University of Illinois, Urbana.

GEOGRAPHY

ARTHUR W. WATTERSON, *Chairman*
Illinois State Normal University, Normal

*Suppressing Evaporation from Water Surfaces. Wyndham J. Roberts, State Water Survey, Urbana.

*Teaching of Conservation of Natural Resources in Illinois Colleges and Universities: A Re-Appraisal. Edward Hamming, Augustana College, Rock Island.

*Forecasting Explosion Conditions in Coal Mines. Charles B. McIntosh, Eastern Illinois State University, Charleston.

*The Changing Function and Structure of the Petroleum Industry of O.E.E.C. Europe. Harold A. Winters, Northwestern University, Evanston.

*Kenya, East Africa: Selected Factors Concerning the Distribution of European Population. Donald R. Petterson, Northwestern University, Evanston.

*A Land-use Map from Census Data—The State of Parana, Brazil, As An Example. Robert L. Carmin, University of Illinois, Urbana.

Kaskaskia Island, A Problem in Isolation. Dalias A. Price, Southern Illinois University, Carbondale.

Problems of Intermountain Grazing. John Trotter, Illinois State Normal University, Normal.

A Challenge for Research in Cartographic Design and Map Use. Clarence B. Odell, Denoyer-Geppert Company, Chicago.

GEOLOGY

CARLTON CONDIT, *Chairman*
Illinois State Museum, Springfield

*Uses and Limitations of Electrical Prospecting for Water Supply. Merlyn B. Buhle, Illinois State Geological Survey, Urbana.

Proposals for Physical and Chemical Testing of Rocks. Paul W. Hughes, Illinois State Geological Survey, Urbana, and R. W. Karpinski, University of Illinois, Navy Pier, Chicago.

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*Electric Log Cross-sections of the Silurian-Devonian Formations of a Part of Western Illinois. L. L. Whiting and Margaret O. Oros, Illinois State Geological Survey, Urbana.

*Source and Occurrence of Brines for Secondary Recovery in Illinois. Richard A. Parizek, Illinois State Geological Survey, Urbana.

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Further Plasticity Studies of Till in East-Central Illinois. Don U. Deere and Paul R. Shaffer, University of Illinois, Urbana.

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Regional Variation in Grain Size in the Aux Vases (Mississippian) Sandstone. Mathias J. Walters and David H. Swann, Illinois State Geological Survey, Urbana.

*Valley-side Sedimentation in Southern Illinois. S. E. Harris, Jr., Southern Illinois University, Carbondale.

*Faulting in the Pomona Area, Jackson County, Illinois. George A. Desborough, Southern Illinois University, Carbondale.

PHYSICS

HAROLD P. STEPHENSON, *Chairman*
Illinois Wesleyan University, Bloomington

*Modern Dielectric Theory Applied to Polymethyldisiloxane Molecules. Martin J. Arvin and Robert C. Etherton, Southern Illinois University, Carbondale.

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SCIENCE EDUCATION, PSYCHOLOGY AND SOCIAL SCIENCE

CLYDE M. BROWN, *Chairman*
Southern Illinois University, Carbondale

Techniques Needed for Production of a Sound-Color 16 mm. Teaching Film. Murray Lincoln Miller, Illinois State Normal University, Normal.

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Materials and Methods in the Use of Materials in Aviation Education. Nelson L. Lowry, Township High School District 214, Arlington Heights.
Earth Science Education. George M. Wilson, Illinois State Geological Survey, Urbana.

ZOOLOGY

Section A

W. D. KLIMSTRA, *Chairman*
Southern Illinois University, Carbondale

A Diurnal Cycle of Liver Weight in Birds. Harvey I. Fisher, Southern Illinois University, Carbondale.
*The Os Clitoridis in the Badger. Donald F. Hoffmeister and John Winkelmann, University of Illinois, Urbana.
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Some Considerations of Human Ecology. George B. Happ, The Principia, Elsah.
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Behavioral Changes in Laboratory Animals Following Treatment with Indole 3-Acetic Acid. William T. Sullivan, Galesburg State Research Hospital, Galesburg.

Section B

LEWIS J. STANNARD, JR., *Presiding*
Illinois Natural History Survey, Urbana

*The Range of Zorotypus hubbardi with an Illinois Record (Insecta: Zoraptera). Garland T. Riegel, Eastern Illinois University, Charleston.
*Mucosubstances in Larval Distomate (Plagiorchioidea) and Monostomate (Pronocephalidae, Notocotylidae) Digenetic Trematodes. F. J. Kruidenier and K. N. Meehra, University of Illinois, Urbana.
*The First Records of Boreus (Mecoptera: Boreidae) in Illinois. Lewis J. Stannard, Jr., Illinois Natural History Survey, Urbana.
Parasitic Protozoa in the Human Mouth. Wayne W. Wantland and John Remo, Illinois Wesleyan University, and D. L. Winquist, Dental Clinic, Bloomington.
*North American Stenus in the advenus Complex Including a New Species from Illinois (Coleoptera: Staphylinidae). Milton W. Sanderson, Illinois Natural History Survey, Urbana.
*Fossil Protozoa from the Keewatin Sediments. Kenneth M. Madison, University of Illinois, Chicago.
*New Species of Eimeria (Protozoa: Eimeriidae) from Mexican Rodents. Norman D. Levine, Virginia Ivens, and Francis J. Kruidenier, University of Illinois, Urbana.

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The Developmental Schema of the Eye. Robert H. G. Monninger, Hines Veteran's Administration Hospital, Hines.

*Observations and New Records of Hymenopterous Egg Parasites in the Lycaenidae (Lepidoptera). John Downey, Southern Illinois University, Carbondale.

Cobalt-60 as a Tag for Recovering Amphibians in the Field. E. L. Karlstrom, Augustana College, Rock Island.

Social Behavior in the Longear Sunfish in Aquaria. David May and Hurst H. Shoemaker, University of Illinois, Urbana.

COLLEGIATE SECTION

HARRY J. FULLER, *University of Illinois, Coordinator*
ROBERT R. MERWICK, *Chairman*
St. Procopius College, Lisle

The Use of the Cobaltous-Bicarbonate-Peroxide Reaction in the Determination of Cobalt and Hydrogen Peroxide. Dave Stockman and Gene Frost, Eastern Illinois University, Charleston.

An Original Derivation of Cauchy's Mean Value Theorem. Eugene Haberman and Ralph Stockhausen, St. Procopius College, Lisle.

Detergent Properties of Some Polyethenoxy Lauryl Ether Sulfates and Phthalates. Arlene Darges, Marianne Jonaitis, and Marguerite Vo, College of St. Francis, Joliet.

Geology of the Pomona Area, Jackson County, Illinois. Larry G. Toler, Southern Illinois University, Carbondale.

*Parasite of Swimbladder of Black Catfish. Kenneth C. Corkum, Aurora College, Aurora.

A Comparative Study of Some Facial and Oral Characteristics. Glenna Carolyn Franke, Illinois Wesleyan University, Bloomington.

Microbial Life in Joliet Waterway. Zaida Calzada, College of St. Francis, Joliet.

*The Developmental Stages of the Frog, Embedded in Plastic. Robert F. Loizzi, Loyola University, Chicago.

Photoreactivation of Bacteria. Lois Boxler, College of St. Francis, Joliet.

The Antigenic Properties of the Slime Produced by Vibrio costicolus. Grace Shramek, Loyola University, Chicago.

*Electrolysis of Aqueous Cyclohexylbutrate. D. Mitchell and D. Frey, Monmouth College, Monmouth.

Phase-angle Shift With a Model Alternator. J. Thompson and W. Olson, Monmouth College, Monmouth.

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AQUATIC BIOLOGY

THE FISH POPULATION OF A SPRING-FED STREAM SYSTEM IN SOUTHERN ILLINOIS

WILLIAM M. LEWIS
Southern Illinois University, Carbondale

The Big Creek Drainage is located in Hardin County near Elizabethtown. The drainage includes 67 square miles. It lies primarily in limestone formations along the Ohio River and is crossed by several major faults. The drainage is composed of three principal streams: Big Creek, Hog Thief Creek, and Goose Creek. The watershed of the streams is mostly forested. All three streams are spring fed. During the drought period of 1952 and 1953 the streams continued to flow, although the flow of Hog Thief was drastically reduced.

During August and September of 1953 observations on the physical character of streams were made. These observations are the basis for the comments on water depth, etc. given below.

In general the streams have bottoms of gravel, boulders, and slab rock. They are shaded throughout most of their length. Fluctuations in water level amount to several feet in the lower part of the drainage, but the greater portion of the stream system undergoes fluctuations of three or fewer feet.

The habitat afforded by the different streams and, in some instances, by different segments of the same stream varies significantly. Big Creek proper is 15 miles long and along its length changes in the streams are evident. The lower extent of Big Creek has deeply cut banks. Pools 30 to 40 feet wide and up to 500 feet in length are interspersed with relatively short riffles approximately 75 feet in length. This portion of the stream is directly affected by changes of water level in the Ohio River. During the August observation period the rate of flow was 123 cubic feet per minute. Temperature of the water was 74° F. at which time the air temperature during the day reached 90°, and night-time temperatures were 60° F. In July, 1954, during a particularly hot period, at which time the air temperature was 91° F., the water temperature was 80° F. Two miles above the Ohio River the stream width was 20 feet. Pools constituted 75% of the water area and the pool depths averaged 3 feet. In August the average rate of flow was 141 cubic feet per minute. In the headwaters of Big Creek several miles upstream from the Ohio River, stream width was 20 feet and pools were 2 feet deep. At the time air temperature ranged from 60° to 90° F., the water temperature was 65 degrees F. In August, 1956, when the afternoon, day-

time air temperature was 83° F., water temperature was 72° to 78° F.

Hog Thief Creek is five miles long and at normal water stages it affords an excellent series of large pools and riffles. It is the least stable of the three streams. During the drought period of 1953 its above-ground flow was greatly reduced. However, there may have been significant water movement in the gravel of the stream bed. Hog Thief is fairly homogeneous throughout its length. It has a width of 15 to 20 feet and pools 50 to 100 feet in length and 2 feet deep. Pools constitute about 70% of the water area. Despite its limited flow, water in Hog Thief Creek does not get particularly warm. Two miles upstream from Big Creek in August, 1953, the water temperature fluctuated from 69° to 75° F., at which time the air temperature ranged from 65° to 90° F. Decker Spring, the largest spring in the drainage area, empties into Hog Thief Creek. Th e water of the spring remains at 56° F. throughout the summer.

Goose Creek is only two miles long. It is quite narrow and would be of little interest except that it has an abundant supply of spring water. It also appears to be less affected by drought. In more critical times such a stream might serve as a reservoir for such species as the smallmouth bass and rock bass. The temperature of Goose Creek was 62° F., at which time the air temperature was 73° F. During August, 1956, when the afternoon-daytime temperature was 84° F., the water temperature of Goose Creek varied from 69° F., in the headwaters to 75° F., in the lower waters. Rate of flow in Goose Creek is 26 cubic feet per minute.

Methods of Study

Three sampling stations were established on Big Creek, three on Hog Thief Creek, and one on Goose Creek. The establishment of the stations was based on changes in the physical condition of the stream and accessibility of the areas. A sampling station consisted of one or two prominent pools and riffles.

The study was carried out during August and September, 1953. There had preceded this sampling a two-year period of sub-normal rainfall. Thus we might anticipate that the springs feeding the stream were reduced in flow.

Sampling was with an electrical shocking device supplemented by a minnow seine. Nets were placed above and below the area to be sampled. Then electrodes were run back and forth through both pools and riffles and all fish that were stunned were dipped with a hand net. This process was continued until fish were no longer obtained. The area was then seined with a minnow seine. Due to water depth at the lower station on Big Creek, it was necessary to modify the usual procedure by using a boat with the electrodes mounted on booms on the bow of the boat.

The fishes were placed in formalin and within a period of one month they were weighed and measured. Where practical, ages were determined by the scale method. For a few species it was possible to estimate the ages by length-frequency distributions. Bodyscale relationships were not calculated; the rela-

TABLE 1.—Growth Rate of Golden Redhorse Taken from Big Creek Drainage in Summer and Fall of 1953.

Age group, years	Number fish	Measured average standard length (mm.)	Calculated standard length in mm. at end of year						
			1	2	3	4	5	6	7
0	1	82	.....	.....	.....	.....	.....	.....	.....
1	58	79	39	.....	.....	.....	.....	.....	.....
2	40	125	37	86	.....	.....	.....	.....	.....
3	11	161	37	80	124	.....	.....	.....	.....
4	2	216	32	75	152	188	.....	.....	.....
5	14	232	42	87	136	178	210	.....	.....
6	2	242	45	104	146	188	215	234	.....
7	1	355	56	143	198	252	288	316	338
Weighted mean standard length (mm.)			41	86	135	184	215	261	338
Total length (inches)			2.0	4.1	6.5	8.8	10.0	12.5	16.0
Annual length increment (mm.)			41	48	67	42	31	22	77

Total length (inches) = 0.048 standard length (mm.) (Lewis and Elders, 1953).

TABLE 2.—Growth Rate of Common Shiner Taken from Big Creek Drainage, Summer and Fall, 1953.

Age group, years	Number fish	Measured average standard length (mm.)	Calculated standard length in mm. at end of year				
			1	2	3	4	5
1	3	54	27	.....	.....	.....	.....
2	30	78	29	57	.....	.....	.....
3	7	98	29	62	82	.....	.....
4	1	103	20	52	71	90	.....
5	1	132	24	40	68	104	126
Weighted mean standard length (mm.)			28	58	79	97	126
Total length (inches)			1.4	2.9	4.0	4.8	6.5
Annual length increment (mm.)			28	29	21	27	22

Total length (inches) = 0.050 standard length (mm.) based on 517 specimens in the standard-length range 17 to 132 mm.

TABLE 3.—Growth Rate of Spotted Bass Taken from Big Creek Drainage in Summer and Fall of 1953.

Age group, years	Number fish	Measured average standard length (mm.)	Calculated standard length in mm. at end of year					
			1	2	3	4	5	6
0	2	46	.....	.....	.....	.....	.....	.....
1	8	127	74	.....	.....	.....	.....	.....
2	5	157	68	125	.....	.....	.....	.....
3	5	189	73	131	168	.....	.....	.....
4	3	190	76	125	159	182	.....	.....
5	5	237	72	129	167	198	223	.....
6	3	215	51	97	138	162	180	204
Weighted mean standard length (mm.)			70	123	160	184	207	204
Total length (inches)			3.4	6.0	7.7	8.8	9.9	9.8
Annual length increment (mm.)			70	54	37	27	23	24

Total length (inches) = 0.048 standard length (mm.) (Carlander, 1950).

TABLE 4.—Growth Rate of Green Sunfish Taken from Big Creek Drainage in Summer and Fall of 1953.

Age group, years	Number fish	Measured average standard length (mm.)	Calculated standard length in mm. at end of year				
			1	2	3	4	5
0	3	46	.....	.....	.....	.....	.....
1	5	56	29	.....	.....	.....	.....
2	10	87	29	59	.....	.....	.....
3	25	93	25	52	71	.....	.....
4	1	163	39	91	131	147	.....
Weighted mean standard length (mm.)			27	55	73	147	.....
Total length (inches)			1.3	2.6	3.5	7.2	.....
Annual length increment (mm.)			27	29	19	16	.....

Total length (inches) = 0.047 standard length (mm.) (Lewis and Elder, 1953).

tionships were assumed to be in the order of a straight line.

In the discussion that follows, the status of each species of fish represented in the Big Creek population is compared to the status of the fish in the southern Illinois area. The area status is based on several years of collecting by various personnel of the Department of Zoology and Cooperative Fishery Research Laboratory of Southern Illinois University.

Common white sucker, *Catostomus commersoni*.—One percent of the total fishes collected. There was no indication of year-class dominances.

Hogsucker, *Hypentelium nigricans*.—Although only two specimens of the hogsucker were obtained, it was surprising to find this fish since it so seldom is collected in the southern Illinois area.

Creek chubsucker, *Erimyzon oblongus*.—The creek chubsucker is not found in dense populations in any of the southern Illinois waters and constituted less than one percent of the total collections in this study. Sixteen of the 17 specimens taken were from Hog Thief, the warmest of the headwater streams.

Golden redhorse, *Moxostoma erythrurum*.—Two percent of the total collection. The oldest specimen taken was in its eighth summer. The majority of the population was made up of one- and two-year-olds with an average standard length of 79 and 125 mm., respectively (Table 1.)

Creek chub, *Semotilus atromaculatus*.—Seventeen taken. The calculated total length at each annulus was 78 and 96 mm. for the first and second years of life, respectively.

Redfin shiner, *Notropis umbratilis*.—Fourteen were taken.

Common shiner, *Notropis cornutus*.—Twelve percent of the total catch. Dense populations of it are rare in southern Illinois. It was particularly abundant in the colder water of Goose Creek. The length-frequency distribution reveals a young-of-the-year peak at 27 mm. and a one-year-old peak at 52 mm. of standard length. There is a suggestion of a peak at 67 mm. which would be the two-year-old group (Fig. 1). The common shiner could also be aged by the scale method (Table 2). The ages arrived at independently by the length-frequency method and scale method corrobated each other.

Bluntnose minnow, *Pimephales notatus*.—Sixteen percent of the total fishes taken. This species, in southern Illinois in general, is not as common as the stoneroller.

Length-frequency distribution of 660 specimens of bluntnose minnows from the drainage revealed a young-of-the-year peak at 27 mm. and a one-year-old peak at 52 mm. (Fig. 1). Approximately 60% of the fish were young-of-the-year, and the majority of the remainder were one-year-olds.

Stoneroller, *Campostoma anomalum*.—Thirty-three percent of the fishes in all

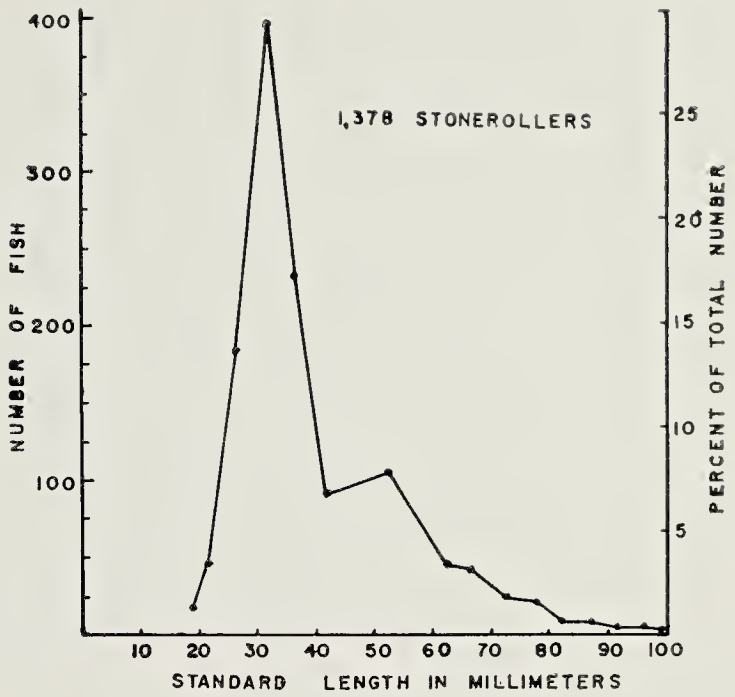

FIG. 1.—Length-frequency distribution of three of the common minnows of the Big Creek Drainage.

TABLE 5.—Growth Rate of Longear Sunfish Taken from Big Creek Drainage in Summer and Fall of 1953.

Age group, years	Number fish	Measured average standard length (mm.)	Calculated standard length in mm. at end of year				
			1	2	3	4	5
0	8	38	.....	.....	.....	.....	.....
1	130	46	22	.....	.....	.....	.....
2	100	64	24	47	.....	.....	.....
3	39	82	27	49	68	.....	.....
4	47	87	25	45	62	76	.....
5	17	105	28	50	67	82	95
Weighted mean standard length (mm.)			24	47	65	78	95
Total length (inches)			1.2	2.2	3.1	3.7	4.6
Annual length increment (mm.)			24	27	18	15	13

Total length (inches) = 0.048 standard length (mm.) (Lewis and Elder, 1953).

samples. It is a very prominent fish in the clear-water streams of southern Illinois area (Lewis and Elder, 1953). It was found that the stoneroller was less abundant in Goose Creek, the coolest of the streams, and in the lower part of Big Creek where the water was quite sluggish. It was most abundant in Hog Thief Creek and upper Big Creek where the environment was intermediate between the two extremes. This area of particular abundance is quite similar to the headwaters of Hutchins and Clear creeks of the southern Illinois area, characterized by dense stoneroller populations (Lewis and Elder, 1953).

The length-frequency of 1,378 stonerollers from the Big Creek drainage shows a peak at 32 mm. in standard length and another at 52 mm. (Fig. 1). Since the sample was taken in August, the 32 mm. peak may be considered to represent young-of-the-year and the 52 mm. peak, the one-year-old fishes. Thus young-of-the-year made up about 70% of the stoneroller population. A large part of the balance of the population was composed of one-year-olds.

Channel catfish, *Ictalurus punctatus*, and yellow bullhead, *I. natalis*.—The channel catfish and yellow bullhead were poorly represented. The total collection included 4 of the former and 3 of the latter species.

Madtom, *Schilbeodes miurus*. — The madtom was represented in the collection by two specimens.

Grass pike, *Esox americanus*.— Only two specimens taken.

American eel, *Anquilla rostrata*.—The collections included only one.

Blackstripe topminnow, *Fundulus notatus*.—This species is quite common in southern Illinois. It is to be seen swimming on the surfaces of most streams and lakes. In the present survey, on a numerical basis, it made up 2% of the catch.

Rainbow darter, *Etheostoma caeruleum*, and Johnny darter, *Etheostoma nigrum*.—The rainbow was by far the most abundant darter in the collections, 10% of the total. It was equally abundant in the coldest water and that of average temperature, but was not abundant in the sluggish waters of the lower portion of the drainage.

Stripe-tailed darter, *Etheostoma kennicotti;* spot-tailed darter, *Etheostoma squamiceps;* and log perch, *Percina caprodes*.—Specimens of each were in the collections. The stripe-tailed darter was particularly abundant in the cold water of Goose Creek. It constituted 17% of collections from Goose Creek but only 3 and 4% in the warmer waters and was absent from the lower portions of the drainage.

Smallmouth bass, *Micropterus dolomieu*.—It was something of a surprise to find a well-established population of smallmouth bass in southern Illinois. It was not as abundant, however, as the spotted bass. Its rate of growth was nor-

mal. Fish in their second summer were the most abundant. These second-summer fish had reached a length of 7.2 inches total length.

Spotted bass, *Micropterus punctulatus.*—Of the various game fishes found in the Big Creek Drainage, the spotted bass probably offers the best possibility for management. The greater abundance of the spotted bass in the drainage, as compared with the smallmouth and largemouth, suggests that the habitat is more suited to it. Spotted bass in all of the age groups were fairly equally represented (Table 3).

Largemouth bass, *Micropterus salmoides.*—Only one largemouth was taken. It is interesting that the environment offered by the clear-water streams in the southern Illinois area permits the dominance of spotted over largemouth bass. Further evidence of this is to be found in a study of the Clear Creek Drainage (Lewis and Elders, 1953).

Warmouth, *Chaenobryttus coronarius.*—Two warmouths occurred in the collection.

Green sunfish, *Lepomis cyanellus.*—The green sunfish is to be found in practically all of the waters of southern Illinois. It seems to prosper in clear water streams such as those of the Big Creek Drainage. It is in this type of environment that one often finds an abundance of the larger specimens of this species. The largest green sunfish taken in the present study was 7.7 inches in total length. Fish in their fourth summer were the most abundant; average total length at this age was 4.4 inches (Table 4). This species contributed two percent of the catch on a numerical basis.

Longear sunfish, *Lepomis megalotis.*—On a numerical basis eight percent of the catch was made up of longear sunfishes. It is found in most of the rivers, streams, and larger lakes of southern Illinois, but it is most characteristic of the clear water streams of this area. The population of the Big Creek Drainage is a typical one. The largest specimens taken were 4.6 inches in total length (Table 5).

Rock bass, *Ambloplites rupestris.*—In southern Illinois the occurrence of the rock bass is unusual. In this study, they were found as a well-established population. The largest specimen taken was 6.5 inches in total length and was in its sixth summer.

Northern muddler, *Cottus bairdii.*—The stenothermic nature of sculpins is well known. This characteristic is shown in the present collections. They represented 12% of the collections of Goose Creek and less than 1% of any other collections.

Discussion

The fish populations of the Big Creek Drainage are of particular interest for several reasons. The stream is one of the few spring-fed or partially spring-fed streams in southern Illinois. The fishes include well-established populations of rock bass, smallmouth bass, spot-tailed darter, and striped-tailed darter, all of which are rare in southern Illinois. The variation in temperature between Goose Creek and the other streams made possible observations on habitat preference by different species. The common shiner, northern muddler, and the stripe-tailed darter exhibited particular preference for the colder water, whereas the bluntnose minnow seemed to avoid the cold water.

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FISHING PRESSURE AND FISHING SUCCESS AT ARGYLE LAKE, McDONOUGH COUNTY, ILLINOIS, AS INDICATED BY CREEL CENSUS

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Introduction

As the purpose of expending money from sale of fishing licenses and from taxes on fisheries management is to provide better fishing for more fishermen, there should be an evaluation of these practices. It is recognized that each body of water presents its own management problems, and, therefore, must be treated individually in the solution of these problems. Evaluation of management problems on a particular body of water should be made with that particular body in mind. Studies of growth rate, species composition, available food, and habitat conditions can give much information concerning fisheries management, but they do not evaluate management directly in terms of fishing success. The creel census is a tool which can be used to this end.

A creel census was taken on Argyle Lake during the summer of 1954. This lake is an artificial impoundment, built and maintained by the Illinois Department of Conservation for public recreation. Argyle Lake is an eutrophic lake of 117 acres surface area and is surrounded by a well-wooded watershed of 3,800 acres. Fishes present at the time of this study were: largemouth bass, *Micropterus salmoides* (Lacepede); bluegill, *Lepomis macrochirus* Raf.; yellow bullhead, *Ameiurus natalis* (LeSueur); channel catfish, *Ictalurus punctatus* (Raf.); walleye pike *Stizostedion vitreum* (Mitchell); and green sunfish, *Lepomis cyanellus* Raf.. Fishing is mainly for bass and bluegill.

The angling success at the onset of this study appeared good as compared to similar lakes in central Illinois. Nevertheless, the bass and bluegill populations of Argyle Lake were beginning to show signs of overpopulation (unpubl., Ill. Dept. Cons.).

Acknowledgments

This work was done under the supervision of Dr. Howard Young and Dr. John D. Parsons. For cooperation thanks are especially due to two men of the Illinois Conservation Department, Mr. Al Lopinot, Fisheries Biologist, and Mr. Harold McLean, Custodian and Game warden at Argyle Lake.

Methods

The census was taken for a total of 32 days during June, July, and August, 1954. An attempt was made to take the census on as many days as possible, and particularly on days when it was judged that the number of fishermen would be large. The method of sampling should probably be termed "haphazard" (Mottley and Embody, 1940). It is be-

lieved that the number and spacing of the census days, however, gave an adequate coverage of the entire season.

On week days there was little angling except during the period from about three hours before sunset to about one hour after it. Weekday censuses were consequently started between 4 and 6 p.m. and were not terminated until all fisherman finished. Thus most early afternoon anglers were counted as they completed their angling day. On week-end days the census period started about 9 a.m. because on these days more anglers began fishing at sunrise than on week days; most of their catches were recorded. Periodically a few anglers fished the entire evening for catfish and bullheads; an attempt was made to contact these anglers by boat and to record their catch.

State rental and privately owned boats were kept at one dock, adjacent to a boat house and parking lot. As the shore line was heavily wooded, access to the lake was difficult except by boat, and there were few bank fishermen. Angling data were usually recorded at the dock. It is estimated that on census days information was obtained from approximately 90% of the fishermen.

Data were recorded by the author on a printed card for each person. The data included: name; adult or child; sex; date; time fishing started; time fishing ended; method of fishing (fly fishing, bait casting, spinning, or still fishing); depth fished (surface, top to three feet, three to ten feet, or ten feet to bottom); and type and color of the most successful bait. (If artificial, its description was recorded by the investigator).

The card also contained space for weights and lengths of each angler's fishes, in tenths of pounds and inches, respectively, for up to 10 bass (legal limit) and 30 bluegills. The numbers caught and the average weight of channel catfish and bullheads were recorded.

Discussion

Fishing methods and success.— The daily fishing pressure in terms of fisherman-hours and the daily fishing success in terms of the number of bluegills, bass and "all species" (total bass, bluegills, and other species) of fishes caught, and the method and depth of angling, are in Table 1. Fishing success in terms of the catch per fisherman-hour is calculated from these totals and is shown in Table 2. Also shown in Table 2 are the percentages of unsuccessful fishermen.

Still-fishing was the most used method among anglers, followed by fly fishing, bait casting, and spinning, in decreasing order. The greatest number of still-fishermen preferred to angle on or near the lake bottom; however, the lowest catch per fisherman-hour was recorded from this depth. As Argyle Lake is relatively new (dam first closed in January, 1950), and as there are few lakes in this section of the state, many of the local fishermen were conditioned to river and creek fishing for catfish and rough species and continued to apply their bottom-fishing techniques on Argyle Lake. Few still-fishermen angled on or near the surface, although those who did enjoyed a relatively high

rate of catch. The over-all rate of catch for still-fishing for bass and bluegills was relatively low, but that for "all species" was high, for most of the catfish and bullheads were caught by this method.

Fly fishing produced the highest catch rate for bluegills and the second highest for bass. Most fly fishermen concentrated their efforts on surface fishing, using cork "poppers" for lures. Though few fly fishermen angled below the surface, the catch rates for depths to ten feet were nearly as high as those for surface fishing.

A small percentage of fly fishermen concentrating their effort on the surface were unsuccessful, while a higher percentage of unsuccessful effort was recorded in the area from just below the surface to a depth of three feet.

Few fisherman angled with spinning tackle; however, this method produced the highest bass catch rate of all methods, 0.37 bass per fisherman-hour. The use of "popper" or "noisy" surface lures was the most successful technique with spinning equipment.

The bass rate of catch for the bait casting method, 0.16 bass per fisherman-hour, was low compared with fly fishing and spinning methods. It was observed, however, that most of the large bass caught were taken by bait casters. As would be expected, very few bluegills were caught by bait casters.

The totals for all methods in Table 2 show that fishing pressure was more intense at the surface than at any depth below the surface. The catch rate at the surface was high compared with that at any depth below the surface.

The catch per fisherman-hour for all methods and depths was 1.18 for all species, 0.95 for bluegills, and 0.18 for bass. Fishing success on Argyle Lake appears good when compared with creel census data obtained on other lakes throughout the country (Carlander, 1953). Bennett and Durham (1951) described success on Ridge Lake, Illinois, as 0.14 bass per fisherman-hour. Recorded at Lake Chautauqua, Illinois, was a catch rate of 0.81 and 0.86 bluegills per fisherman-*day* and 0.14 and 0.09 bass per fisherman-*day* for two summers (Starrett and McNeil, 1952). In terms of the fisherman-day the catch rate for these species on Argyle Lake was 2.75 bluegills and 0.25 bass.

Distribution of catch among fishermen.—The data for individual fishermen were arranged in order of successful trips, which were determined by the number of bass, bluegills, and all species caught. The percentage of fishermen was plotted against the percentage of total catch of all fishermen for each species.

It was found that one-third of the fishes caught were taken by 5% of the fishermen, and one-half of the total catch was accounted for by only 20% of the total anglers. Forty-five percent of the fishermen were unsuccessful in taking any fishes. As bluegills composed a large share of the total catch, the plotted curve for this species lies close to the one just discussed, with the noted exception that 56% of the anglers were unsuccessful in catching this species. However, in the case of bass 5% of the anglers took 50% of the total catch, and 2% of the fishermen caught 27% of the bass. However,

TABLE 1.—Catch of Bass, Bluegills, and All Species, Argyle Lake, 1954.

	No. fishermen	Total hours	No. all species	No. bass	No. bluegills
All methods	717	2,079	2,445	371	1,946
surface	285	766	1,160	271	799
down to 3 ft.	144	447	463	43	398
3 to 10 ft.	139	433	576	52	517
below 10 ft.	149	423	246	5	160
Fly fishing	255	716	1,245	246	998
surface	2?2	641	1,113	238	875
down to 3 ft.	17	45	80	2	77
3 to 10 f	6	30	52	6	46
below 10 ft.	0	0	0	0	0
Bait casting	91	265	53	42	11
surface	38	97	19	19	0
down to 3 ft.	38	118	16	15	1
3 to 10 ft.	11	34	18	8	10
below 10 ft.	4	16	0	0	0
Spinning	26	68	43	25	18
surface	12	28	17	12	5
down to 3 ft.	9	18	8	7	1
3 to 10 ft.	5	22	18	6	12
below 10 ft.	0	0	0	0	0
Still-fishing	345	1,030	1,104	58	937
surface	3	10	11	2	9
down to 3 ft.	80	266	359	19	319
3 to 10 ft.	117	347	488	32	449
below 10 ft.	145	407	246	5	160

82% of the total anglers were unable to obtain bass.

This eccentricity among individual anglers may be influenced by two factors: 1) skill has an important bearing on success; and 2) fishermen selectively "fish for" a particular species and, therefore, are more successful in taking that species.

A comparison was made between the angling methods of unsuccessful fishermen and the most successful 10% of the anglers. The following was noted concerning bass fishing. The most successful fishermen did a great amount of fly casting, but little bait casting at the surface, compared with unsuccessful fishermen. Still-fishermen caught few bass at the surface, and the percentage of most successful bass fishermen using this method decreased with increase in depth.

The only significant difference between the methods of fishermen who were most successful or unsuccessful in taking bluegills, was noticed

TABLE 2.—Success in Fishing for Bass, Bluegills, and All Species, Argyle Lake, 1954.

	Fish per fisherman-hour			Per cent unsuccessful fishermen
	All species	Bass	Bluegills	
All methods	1.18	0.18	0.95	36
surface	1.50	0.35	1.03	28
down to 3 ft	1.04	0.10	0.89	38
3 to 10 ft	1.33	0.12	1.20	33
below 10 ft	0.58	0.01	0.38	51
Fly fishing	1.74	0.34	1.40	20
surface	1.74	0.37	1.35	22
down to 3 ft	1.79	0.05	1.71	59
3 to 10 ft	1.72	0.20	1.52	0
below 10 ft	0.0	0.0	0.0	0
Bait casting	0.21	0.16	0.04	69
surface	0.07	0.20	0.0	68
down to 3 ft	0.14	0.13	0.01	71
3 to 10 ft	0.52	0.24	0.29	55
below 10 ft	0.0	0.0	0.0	0
Spinning	0.63	0.37	0.25	27
surface	0.60	0.43	0.18	25
down to 3 ft	0.44	0.45	0.56	33
3 to 10 ft	0.83	0.28	0.55	20
below 10 ft	0.0	0.0	0.0	0
Still-fishing	1.11	0.06	0.93	39
surface	1.07	0.19	0.87	33
down to 3 ft	1.36	0.07	1.20	29
3 to 10 ft	1.41	0.09	1.30	33
below 10 ft	0.61	0.01	0.39	50

among still-fishermen, where the most successful anglers fished from just below the surface to a depth of ten feet.

With the above discussed exceptions, there were but small differences in the methods used by the most successful or unsuccessful anglers in taking fishes.

A comparison of fishing success with the number of trips per fisherman per year is given in Table 3. Fishermen were divided into those fishing once, twice, or three or more times per season. For each group, fishing pressure, catch, and unsuccessful fishermen are given in percentages and rates of catch in fishes per fisherman-hour. The catch rate is increased significantly with an increase in number of trips (Table 3). It is apparent that the success of individual fishermen is directly associated with experience. Bennett

TABLE 3.—Fishing Success and Number of Trips per Year by Fishermen, Argyle Lake, 1954 (in percentages).

	Three or more trips	Two trips	One trip
Of total fishermen	4.	7.3	88.0
Of total fisherman-hours	11.6	12.9	75.5
Of total catch			
all species	26.2	13.8	60.0
bass	24.4	18.9	56.7
bluegills	26.5	13.1	60.4
Catch per fisherman-hour			
all species	2.29	1.09	0.81
bass	0.23	0.17	0.09
bluegills	2.06	0.93	0.73
Of unsuccessful fishermen	12.5	20.0	45.9

and Durham (1951) showed this to be true on Ridge Lake, Illinois, where catch rates increased from 0.14 to 0.19 bass per fisherman-hour for fishermen making one to four trips and those making five or more trips, respectively. Which factor of this association is cause and which is effect, if that relationship exists, cannot be stated.

Seasonal pressure and yield estimates.—Values for daily fishing pressure in number of fisherman-hours were plotted and a curve, fitted to these by inspection, was extended to cover the periods from May 29, 1954, to September 10, 1954. At other seasons pressure became negligible. From the areas enclosed by the curves the fishing pressure for the summer season was calculated to be 9,550 fisherman-hours, or 81.5 fisherman-hours per acre. The average length of the fishing trip was found to be 2.8 hours, and this applied to the above figures gave 3,300 fisherman-days per year and 31.8 fisherman-days per acre per year. Bennett and Durham (1951) reported 105 and 155 man-hours of angling per acre on Ridge Lake for two fishing seasons; Starrett and McNeil (1952) reported 18.2 man-hours. The number of man-days of angling per acre per year for Argyle Lake (31.8) is about the average value found in 32 studies summarized by Carlander (1953).

An estimate of the numbers of fishes caught throughout the 1954 summer season on Argyle Lake was obtained for bluegills, bass, and all species by applying the mean catch per hour of these species (Table 2) to the above estimate of total fisherman-hours per year. It was found that (fish per acre per year values in parentheses) an estimated 9,040 (77.2) bluegill, 1,690 (14.9) bass, and 11,210 (96.0) fishes of all species were caught per year and per acre per year during the 1954 season

on Argyle Lake. The numbers of bullheads and catfish caught were calculated as 506 fish per year and 4.1 fish per acre per year.

Many fishes were returned to the water after capture by the fishermen. The percentage of fishes kept and actually taken from the lake were: bluegills, 34.1; bass, 62.5; bullheads and catfish, 95.5; and all species, 58.7. These percentages of the total catch of each species per year gave the following figures for the "take home" harvest in numbers of fishes per year (values per acre per year in parentheses): bluegills, 3,080 (26.3); bass, 1,055 (9.0); bullheads and catfish, 472 (4.0); and all species, 4,540 (39.3)

The estimated total harvest in pounds of fishes was calculated by multiplying the average weights for each species by the estimated catch per year. These average weights were: bass, 0.220 lbs.; bluegills, 0.139 lbs.; and bullheads and channel catfish, 0.785 lbs. Estimated total harvest in pounds of fishes taken from Argyle Lake in 1954 (values per acre per year in parentheses) are bluegills, 428 (3.7); bass, 228 (2.0); bullhead and catfish, 360 (3.2); and all species 1,016 (8.9) lbs. of fish per year.

According to a summarization (Carlander, 1953) of available data on annual yield of fishes in pounds per acre by angling in artificial lakes and ponds, the harvest of Argyle Lake, 8.9 lbs. per acre per year, was relatively low. If it may be assumed that Argyle Lake supports between 100 and 500 lbs. of fish per acre, then the total harvest of 8.9 lbs. per acre per year is 8.9 to 1.8% of the standing crop. It is the belief of the author that the yield to anglers could not be increased enough to impair materially the population of fishes or even to help control overpopulation. It is probable, however, that an angler education program on Argyle Lake would greatly increase the harvest and thereby make the lake a greater asset to the fishing public.

Summary

1. A creel census was taken on Argyle Lake, McDonough County, Illinois, during the summer of 1954. This lake is an artificial impoundment used for recreational purposes only.

2. Data were collected on the species, number of individuals, length and weight of fishes caught by fishermen, amount of time spent per fisherman, fishing method, and bait used. Census was taken on 32 haphazardly selected days of the 1954 fishing season. It is believed that the number and spacing of the census days gave adequate coverage of the entire season.

3. Still fishing was the most used method, followed by fly fishing, bait casting, and spinning, in decreasing order. a) Most still fishermen preferred to angle on or near the lake bottom; however, the lowest catch per fisherman-hour was recorded from this depth. b) Fly fishing produced the higest rate of catch for bluegills and the second highest for bass. Most fly fishermen concentrated on surface fishing. c) Few fishermen angled with spinning tackle; however, this method produced the higest catch rate of bass. d) The catch rate for bass using

bait casting was low, compared with fly fishing and spinning methods.

4. The catch per fisherman-hour for all methods and depths was 1.18 for "all species", 0.95 for bluegills, and 0.18 for bass. Fishing success on Argyle Lake appeared good when compared with creel census data obtained on other lakes throughout the country.

5. A large portion of the total catch was accounted for by a small percentage of the fishermen. Only small differences exist between the method used and depth fished by the unsuccessful fishermen and the most successful ten percent of the anglers. A comparison of fishing success and the number of fishing trips made per year by individual fishermen showed an association of success and experience.

6. Seasonal pressure was estimated at 81.5 fisherman-hours or 31.8 fisherman-days per acre per year.

7. An estimated 77.2 bluegills, 14.9 bass, 4.1 bullheads and catfish, and 96.0 fishes of all species were caught per acre per year during the 1954 season.

8. Total calculated harvest in pounds of fishes taken from the lake per acre per year is: bluegills, 3.7; bass, 2.0; bullheads and catfish, 3.2; and all species, 8.9 pounds.

9. This harvest was estimated to be 1.8 to 8.9% of Argyle Lake's standing crop.

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FLOTATION OF FISHES FOLLOWING STUNNING BY ELECTRICAL SHOCK

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INTRODUCTION

When sampling fish populations by use of electrical shock, one encounters variations in the number of fishes taken. Variations in catch occur on different days in the same waters, and the catch of a species may be out of proportion to its abundance. The present study was undertaken with the objective of determining the cause of these variations in catch.

Preliminary work indicated that much of the difference in catch is associated with variation in flotation of the fish following their being stunned. Failure to capture non-floating stunned fish is particularly important in turbid waters. To understand the cause of differences in flotation, all environmental factors that were thought to be important in this regard were investigated. A consideration of each of these factors is given below.

POSSIBLE FACTORS

Salt content of water.—The first environmental variable investigated was salt content of the water. It was not possible to demonstrate that a variation in salt content, of the magnitude occurring in most midwestern situations, had any significant effect upon the flotation of fishes.

Barometric pressure.—The effect of atmospheric pressure was studied by utilizing a steel cylinder equipped with an air exhaust system. By this means an aquarium containing fish was subjected to lowered barometric pressures equal to any changes which might normally occur. Although it was possible to make a stunned fish float by dropping the barometric pressure the equivalent of two inches of mercury, such a drop of atmospheric pressure would be rare in nature. Hence, it was felt that a more effective variable must exist.

Temperature and temperature changes.—Since winter-time collecting with electrical equipment was observed to be poor, it was thought that stunned fishes might float more readily at higher temperatures. Fishes were held at various temperatures and shocked. No positive correlation was obtained from this work.

To determine the effect of temperature change upon flotation, a group of fishes that had been held for several hours at a particular temperature was divided into two groups, one of which was moved to water of the same temperature and the other to water varying from 3 to 23 degrees warmer; after 5 minutes they were shocked, using 110 volts alternating current. Forty-six

trials were conducted, with beginning water temperatures from 33° to 72° F. The sample in each trial consisted of one, two, or three fishes. The species utilized included: the green sunfish, *Lepomis cyanellus;* white crappie, *Pomoxis annularis;* goldfish, *Carassius auratus;* yellow bullhead, *Ictalurus natalis;* white sucker, *Catastomus commersonii;* largemouth bass, *Micropterus salmoides;* Creek chubsucker, *Erimyzon oblongus;* steel-colored minnow, *Notropis whipplei;* longear sunfish, *Lepomis megalotis;* and golden shiner, *Notemigonus crysoleucas* . The green sunfish floated if the increase in temperature amounted to as much as 8° F. The largemouth bass floated at an 8-degree increase but not at 6-degree increase. The goldfish and steel-colored minnow floated when the temperature was increased 10-degree The creek chubsucker did not float with a 10-degree increase in temperature. The yellow bullhead could not be made to float, even with a maximum increase of 22 degrees, although observation on this species was somewhat limited. The crappie was not entirely predictable even with extremes of temperature change. It is evident that a variation in flotabilty exists between species. This is further confirmed by the findings given below which refer to the effect of changes in depth.

Changes in depth.—To determine the effect of depth changes upon flotation, fishes were held in cages suspended in steel drums at depths of 8 inches, 20 inches, and 34 inches. At the end of 24 hours the fish at 20 and 34 inches of depth were moved up to 8 inches and all fishes were shocked, using 110 volts alternating current; in some instances they were shocked at 34 inches as a control procedure. A total of 77 trials was conducted, utilizing from 1 to 4 fish per trial. The trials were conducted at temperatures ranging from 36° to 75° F., but in all instances the temperature was constant during the experiment and precautions were taken to avoid thermal stratification within the holding tank. In practically all instances, when the fish were held at 20 inches or at 34 inches and then moved to 8 inches and shocked, immediate flotation occurred in the green sunfish, largemouth bass, creek chubsucker, longear sunfish, goldfish, steel-colored minnow, and some golden shiners, but not in the yellow bullhead. There were instances, particularly in the crappies, where fish that were held at eight inches floated.

Discussion

It becomes apparent from our observations that changes in temperature and depth, of magnitudes to be found in nature, are important in determining whether or not a fish will float or sink following stunning by electrical shock. The magnitude of the change required to produce flotation is approximately 8 degrees in temperature or 12 inches in depth. It is also apparent that there may be considerable variation in the flotation of different species of fishes. For example, the yellow bullhead did not float when subjected to rather extreme changes in temperature and depth. A rather interesting situation did occur in regard to this species. In one instance, when the fish was

stunned, it sank and came to rest with its head directed toward the surface. As it commenced to recover, spasmodic fin action caused it to surface.

The variation between species requires a great deal of additional observation, but there may be an association between the fishes having a well-developed pneumatic duct and the more recent fishes that have lost this connection between the swim bladder and the esophagus. This is suggested by the fact that, in each instance when the bullheads were subjected to changes in temperature and depth, they would commence to release air bubbles from the operculum approximately five minutes after they were subjected to the change.

The green sunfish, the species most thoroughly studied in the present work, apparently is able to adjust to the changes in temperature or depth in approximately 30 minutes.

The relationship between these findings and the electrical sampling of fish populations under field conditions is of significance. In a lake, one might commonly run into a situation where fishes would move from colder to warmer water, and in any habitat one might encounter fishes moving from a greater to a lesser depth. One is led to speculate as to the possibility of causing fish to move to shallow water prior to shocking.

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FISHERY VALUES OF A RESTORED ILLINOIS RIVER BOTTOMLAND LAKE

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During the past century certain of man's activities have had a direct effect upon the fisheries of Illinois. Intensive agriculture on the watersheds of the lakes and streams has accelerated the rate of erosion on the lands and the rate of siltation of the waters. Industrial and sewage wastes have polluted in varying degrees many of the natural waters of the State. Navigation dams on the larger rivers have reduced stream flow and, through the operation of the gates in these dams, fish often are exposed to severe fluctuations of water level. Thousands of acres of lakes and sloughs adjoining rivers have been drained for agricultural purposes. Many people consider these activities as evidence of progress, and, because they are unaware of values associated with natural areas, assume that agriculture has a higher economic use. The purpose of this paper is to present the economic importance of the sport and commercial fisheries of Lake Chautauqua, a restored Illinois River bottomland lake.

Description of Lake Chautauqua

Lake Chautauqua is located in Mason County, near Havana, Illinois. The area now covered by the lake was originally a series of lakes and sloughs adjacent to, and connected with, the Illinois River. Following World War I these lakes and sloughs were drained and leveed from the river for agricultural purposes by the Chautauqua Drainage and Levee District. In the fall of 1926 a flood on the Illinois River broke the levees and flooded the District. The land was not reclaimed for agriculture, so that the venture was a financial failure. In 1936 the U. S. Biological Survey (predecessor of the Fish and Wildlife Service) purchased the flooded drainage district for use as a migratory waterfowl refuge. By 1940, the levees had been repaired and water control gates and spillways installed. During moderate to high river stages the Illinois River may overflow into the lake. According to Stall and Melsted (1951:10) Lake Chautauqua covers 3,562 acres at "normal pool elevation", 435.0 feet mean sea level.

Procedure

On April 15, 1950, a cooperative fishery research program was started at Lake Chautauqua by the Illinois Natural History Survey, Illinois Department of Conservation, and the U. S. Fish and Wildlife Service. As part of this program, a creel census was conducted from 1950 through 1954 in the manner described by Starrett and McNeil (1952: 5-6). Fishing during the fall and winter months at the lake was restricted to certain parts of the lake and, prior to 1954, no fishing

was permitted on the lake during the duck hunting season. The Federal Service allowed trot-line fishing on the lake in 1954 and catch records were kept on this fishery.

Prior to 1951, commercial fishing on the lake was limited to wing-net fishing which was permitted from about the middle of March to the first of October. Since 1951, commercial seining has been allowed each year during September. In 1952, several commercial fishermen using wing-nets started "round-up" fishing on the lake, an effective method for taking bigmouth buffalo, *Ictiobus cyprinellus*. The inauguration of seining and "round-up" fishing increased the commerial fishing pressure and catch. Commercial fishery statisics for the lake were compiled from the monthly reports of wing-net catches prepared by the commercial fishermen and from the records of daily seine hauls kept by the writer.

Sport Fishery

A description of the sport fishery at Lake Chautauqua is given by Starrett and McNeil (1952). The following fishes dominated the pole-and-line catch at Lake Chautauqua: crappies, *Pomoxis annularis* and *P. nigromaculatus;* bluegills, *Lepomis macrochirus;* freshwater drum, *Aplodinotus grunniens;* and yellow bass, *Roccus mississippiensis*. The remainder of the pole-and-line catch consisted of: channel catfish, *Ictalurus punctatus;* largemouth bass, *Micropterus salmoides;* white bass, *Roccus chrysops;* and 15 other species. The pole-and-line catch from 1950 through 1954 is summarized in Table 1. Fishing success at the lake varied from an average of 0.6 fishes caught per hour in 1952 and 1953 to 0.8 fishes in 1954. The catch figures indicate, however, that fishing varied considerably more from year to year than is suggested by the catch-per-hour data. Fishing pressure by pole-and-line fishermen at Lake Chautauqua ranged from 5,675 fisherman-days in 1953 to 13,717 days in 1951. The wide range in the annual number of fisherman-days reflected the fishing success, since the fishing pressure at Lake Chautauqua tended to vary directly with fishing success. The total annual fishing pressure at Lake Chautauqua might be expected to double, if good fishing were available at the lake throughout the summer.

Few people fish the lake specifically for largemouth bass; the bass caught are usually taken by anglers fishing for crappies or bluegills.

Complete data on trot-line catches are available only for 1954 (Table 2). Channel catfish and bullheads, *Ictalurus* spp., comprised 52.5% of the trot-line catch. These species formed only a small part of the pole-and-line catch (Table 1). Trot-line fishermen took few pan and game fishes (Table 2), but they were able to catch more catfish and bullheads than was possible with pole-and-line.

Costs of Travel

The average fishing party at Lake Chautauqua consisted of two persons. Home addresses of the fishermen recorded on creel census cards were used to determine the distance each party traveled. The exact mileage traveled by the fishermen was

TABLE 1.—Summary of Creel Census Data (Pole-and-Line Fishermen) at Lake Chautauqua, Illinois, 1950 Through 1954.

Kinds of fishes	Number of fishes caught				
	1950	1951	1952	1953	1954
Crappie	10,096	35,496	18,422	12,510	32,151
Bluegill	7,626	9,335	8,316	1,680	15,787
Freshwater drum	9,459	4,274	4,930	898	4,535
Yellow bass	5,222	2,590	2,792	448	3,160
Channel catfish	1,205	1,206	1,120	321	884
Largemouth bass	1,347	1,105	1,240	726	564
White bass	14	805	909	69	319
Other species	1,853	1,515	1,726	983	2,948
Total number caught	36,822	56,326	39,455	17,635	60,348
Estimated weight (pounds)[1]	17,717	22,180	21,535	9,414	36,442
Anglers	10,499	13,717	12,230	5,675	13,357
Hours fished	53,735	76,768	71,126	29,235	78,320
Fishes caught per hour	0.7	0.7	0.6	0.6	0.8
Fishes caught per fisherman-day	3.5	4.1	3.2	3.1	4.5

[1] Based on mean weights of fish weighed during creel census survey.

not determined, but the approximate mileage was calculated by marking zones on an Illinois road map, using Lake Chautauqua as the center point, and drawing in concentric circles with radii of 25, 50, 75, etc. miles from the lake. A summary of all the recorded trips to the lake (Table 3) shows that 71.5% of the parties drove between 26 and 50 miles. The majority came from the nearest metropolitan counties, Peoria and Tazewell. Fishing at the lake attracted few anglers living more than 75 miles from the lake. Anglers traveling more than 100 miles were mostly from the Chicago metropolitan area (151- to 175-mile zone). Nearly all the out-of-state anglers accompanied resident anglers and had not come to Illinois for the purpose of fishing at Lake Chautauqua.

The average distance traveled to the lake by fishing parties, excluding out-of-state fishermen was about 40 miles, or 80 miles round-trip.

The cost, in 1955, of driving an automobile one mile (excluding depreciation, insurance, and licenses) was $0.035 as determined by the American Automobile Association (Anon., 1956:38). The cost of transportation for each fishing party to Lake Chautauqua for the average distance of 80 miles at $0.035 per mile was $2.80.

Other Sport Fishing Costs

Most of the anglers at Lake Chautauqua brought their lunches

TABLE 2.—Composition of Trot-Line Catch of 1,830 Sport Fishermen at Lake Chautauqua, Illinois, 1954.

Kinds of fishes	Number caught	Per cent of total number
Freshwater drum	3,055	31.1
Bullhead	2,054	21.0
Channel catfish	3,086	31.5
Carp	369	3.7
Bluegill	588	6.0
Crappie	301	3.1
Yellow bass	206	2.1
Other species[1]	144	1.5
Totals	9,803	100.0

[1] 11 kinds of fishes including 21 largemouth bass.

and returned home the same day, so that expenditures for meals and lodging were negligible.

Inexpensive cane poles and live baits were used by most fishermen at Lake Chautauqua, although some still fishing was done with rods and reels of various costs. The number of hooks and sinkers lost per trip on sunken logs was quite high. The estimated, prorated cost for fishing tackle per fishing party at Lake Chautauqua was $0.50, and the cost for live bait per fishing party was $0.75.

Nearly all the fishing at Lake Chautauqua was done from boats. From 1950 through 1954, most of the boats used on the lake were rented from liverymen at the lake. The average cost for boat rental was $1.40 per fishing party trip.

The use of outboard motors was not permitted on the lake until 1952. The prorated and operating costs of an outboard motor per fishing party trip was determined to be $1.25. To standardize the fishing costs for all five years it was considered advisable to include the outboard motor costs in the 1950 and 1951 fishing costs.

SPORT FISHERY VALUES

Bellrose and Rollings (1949:12) assigned recreational values of $2.50 per pound for largemouth bass and $0.75 per pound for other fishes taken by anglers. In the present paper, sport fishing values were separated into recreational and yield values. The recreational values were based on the amount of money anglers spent to take fish at the lake; yield values were determined from the market price of the fish caught by angling.

Recreational value, as used here, is the amount of money anglers spend per annum to fish at the lake. This covers expenditures for transportation, boats, live bait, tackle, outboard motors, and miscellaneous items. The derivations of these various fishing expenses, other than miscellaneous

TABLE 3.—Travel by Fishing Parties (Two Men) from Homes to Lake Chautauqua, Illinois, 1950 Through 1954.

Miles, origin to Lake Chautauqua	Number trips	Per cent, total number trips
0 to 25	4,359	19.6
26 to 50	15,909	71.5
51 to 75	1,152	5.2
76 to 100	231	1.0
101 to 125	56	0.3
126 to 150	67	0.3
151 to 175	397	1.8
176 to 200	4	.....
201 to 225	1	.....
Out of State	69	0.3
Totals	22,245	100.0

items, are given in the two preceeding sections. The cost for an average fishing trip to Lake Chautauqua was computed as follows:

Transportation	$ 2.80
Boat rental	1.40
Live bait	0.75
Tackle	0.50
Outboard motor	1.25
Miscellaneous items (licenses, candy, and beverages)	1.00
Total	$ 7.70

The cost per angler trip was $3.85 since the average number of persons comprising a trip or party to the lake was two. The above costs are also applicable to trot-line fishing.

The recreational values of the sport fishery at Lake Chautauqua (1950 through 1954) are given in Table 4. The calculated average annual recreational value for this period was $44,127.16.

The yield values of the sport fishery at Lake Chautauqua are based on the local wholesale prices (legal or illegal) of the fish caught. These prices, for undressed fish, averaged $0.25 per pound for the species taken at Lake Chautauqua. The estimated numbers of pounds of fish taken annually by anglers (Tables 1 and 2) have been used in calculating the yield values of the Lake Chautauqua sport fishery (Table 4).

TABLE 4.—Calculated Annual Sport Fishery Values of Lake Chautauqua, Illinois, 1950 Through 1954.

Year	Recreational value	Yield value
1950	$40,421.15	$4,429.25
1951	52,810.45	5,545.00
1952	47,085.50	5,383.75
1953	21,848.75	2,353.50
1954[1]	58,469.95	12,687.75

[1] Includes trot-line fishing. Calculated recreational value of trot-line fishery was $7,045.50 and calculated yield value was $3,577.25.

Commercial Fishery Values

The principal species of fishes taken commercially at Lake Chautauqua are: bigmouth buffalo; carp, *Cyprinus carpio;* freshwater drum; and channel catfish. A summary of the annual commercial yields and values of the catches at Lake Chautauqua (1950 through 1956) is given in Table 5. The yearly differences in the commercial yields at Lake Chautauqua were caused by: 1) variations in annual fishing pressure; 2) changes in fishing conditions, methods and devices; and 3) fluctuations in fish populations. The yield in 1950 was exceptionally low because fishermen confined all of their efforts to conventional wing-net fishing.

The calculated average annual value of the commercial catch of fishes from 1951 through 1956 was $24,883.70. The highest calculated annual commercial yield value during the past 7 years at Lake Chautauqua was $32,136.58 in 1954; during that year the reported value of the entire Illinois River catch amounted to only $257,450.00 (unpubl.).

Most of the commercial fishermen that fish at Lake Chautauqua also fish in other waters, so that only a part of the value of their tackle and equipment can be assigned to the Lake Chautauqua fishery. The prorated value of the tackle and equipment used in 1954 on Lake Chautauqua was $4,500.00.

TABLE 5.—Annual Yield and Calculated Value of Fish Taken Commercially at Lake Chautauqua, Illinois, 1950 Through 1956.[1]

Kinds of fish	Weight in pounds for designated years						
	1950	1951	1952	1953	1954	1955	1956
Carp	51,996	79,795	52,156	25,211	58,619	34,473	29,952
Buffalo	68,114	136,816	186,810	165,361	186,795	161,355	142,267
Freshwater drum	15,908	11,144	31,009	34,043	64,090	59,160	28,740
Channel catfish	7,057	5,208	7,940	4,380	13,938	13,084	16,704
Other species	1,179	833	1,754	50	119	41	56
Total catch	144,254	233,796	279,669	229,045	323,561	268,113	217,719
Value	$13,273.08	$21,108.60	$28,075.99	$23,150.65	$32,136.58	$23,491.17	$21,339.18

[1] Based on yearly average local wholesale prices for undressed fish.

Discussion

The fishery of the Illinois River valley is primarily a lake fishery; although some sport and commercial fishing is done in the Illinois River channel, most of the fishing is confined to the shallow, mud-bottomed lakes adjacent to the river channel. Most of these bottomland lakes are either connected with the river, or are subject to the overflow from it.

Between 1904 and 1922, a number of the lakes in the Illinois River bottomland were drained and leveed from the river for agricultural purposes. To date only four of these drainage districts have been reflooded; three of them are operated and managed as privately owned, duck-shooting clubs and the fourth, Lake Chautauqua, is a governmentally controlled wildlife refuge.

Public fishing waters in Illinois have not been increased in proportion to the increase in population and interest in fishing. In 1950, Jenkins and Walraven reported on potential conservation areas along the Illinois River from Hennepin to Grafton. These writers stated (1950:78) that, "While ideally all of the river bottom areas should be returned to the river which made them and which can and will reclaim them at will, some of these areas are more feasible for immediate conservation development". In that report they listed eight drainage and levee districts covering 51,861 acres which they believed might be available for acquisition and early development. Such restored lakes would be used for recreation and for the storage of river flood-waters.

These former bottomland lakes, now in drainage and levee districts, at one time were considered excellent commercial and sport fishing waters. The present investigation indicates that these areas would again furnish good fishing if they were reflooded. In 1954, the total calculated value of the fishery of Lake Chautauqua was $103,294.28, or $29.00 per acre. In addition to the fishery value a restored bottomland lake also has wildlife, boating and flood-storage values.

Summary

1. In Illinois, thousands of acres of lakes and sloughs adjoining rivers have been drained for agricultural purposes. Many conservationists believe that certain of these drainage and levee districts should be reflooded. Lake Chautauqua (near Havana) is a reflooded drainage district along the Illinois River, on which a cooperative fishery research program has been in progress since 1950.

2. A five-year creel census (1950 through 1954) was made at Lake Chautauqua. The principal species of fish taken by anglers were crappies, bluegills, freshwater drum, and yellow bass.

3. Fishing success during the five-year creel census period ranged from a low of 0.6 fishes per hour in 1952 and 1953 to a high of 0.8 fishes in 1954.

4. Fishing pressure by pole-and-line fishermen ranged from 5,675 man-days in 1953 to 13,717 man-days in 1951.

5. The highest annual catch was made in 1954 when anglers took 60,348 fishes on pole-and-line.

6. The estimated weight of the fishes caught by pole-and-line fishermen ranged from 9,414 pounds in 1953 to 36,442 pounds in 1954. The highest annual per acre yield by pole-and-line fishing (1954) was 10.2 pounds.

7. Trot-line creel data were available only for 1954. In that year a total of 9,803 fishes were caught on trot-lines by 1,830 fishermen. The estimated weight of the 1954 trot-line catch was 14,309 pounds.

8. Calculated annual yield values (values of fish as food) of the sport fishery ranged from $2,353.50 in 1953 to $12,687.75 in 1954 (the 1954 value included the trot-line as well as the pole-and-line catch).

9. The calculated average annual recreational value (cost of fishing, which included tackle, boats, transportation, etc.) was $44,127.16. The calculated recreational value in 1954 was $58,469.95.

10. The calculated average annual value of the commercial fish catch from the lake from 1951 through 1956 was $24,883.70. The calculated value of the 1954 catch was $32,136.58.

11. The estimated prorated value of commercial tackle and equipment used at the lake was $4,500.00.

12. The calculated total fishery value in 1954 at Lake Chautauqua was $103,294.28 or $29.00 per acre.

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LITERATURE PERTAINING TO FORMATION OF ACID-MINE WASTES AND THEIR EFFECTS ON THE CHEMISTRY AND FAUNA OF STREAMS

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Introduction

The concurrent increase in population centers and large industrial development has placed such a heavy demand upon both the surface and the underground water resources that a general water shortage seems imminent. Water has become one of the most strategic engineering materials and is a natural resource which must be conserved. The effects of acid wastes from coal stripmines upon this resource represent one of the most serious pollution problems.

Little attention has been given to this type of pollution, though coal mining as an industry has been carried on for nearly a century and a half. The public, in areas where such pollution occurs, is aware of its deleterious effects on stream fishes under extreme conditions. However, this awareness does not encompass the effects of acid-mine water of varying degrees of acid intensity on the characteristic stream chemistry or on the stream fauna other than fishes.

Basically, abatement will depend upon data obtained from studies of the factors which enter into the production and delivery of acid-mine water into streams (Braley, 1954a; Parsons, 1956). The success of an abatement program will depend upon the evaluation of a multiplicity of factors involved in the various aspects of acid-mine water pollution. It is the purpose of this paper to present a review of the literature pertaining to three such aspects: 1) formation of acid-mine water; 2) effect of acid-mine water on stream chemistry; and 3) effect of acid-mine water on stream fauna.

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Formation of Acid-Mine Water

Three forms of iron sulfide are thought to be responsible for the formation of acid-mine water: 1) pyrites (Winchell, 1907; Patrick, 1933; Trax, 1933); 2) marcasites (Frost and Streeter, 1924; Carpenter and Herndon, 1933; Herndon and Hodge, 1936; Hodge, 1938; U. S. Public Health, 1942; Hoffert, 1947); and 3) black amorphous pyrite (Braley, 1954b). These forms

differ not only in crystalline form (Hoffert, 1947; Braley, 1954b), but also in rate of reaction, resultant, pH, and grams of sulfate produced (Braley, 1954b).

Many workers believe the oxidation of iron sulfide is entirely chemical (Frost and Streeter, 1924; Patrick, 1933; Trax, 1933; Burke and Downs, 1938; Hodge, 1938; U. S. Public Health, 1942; Hoffert, 1947). It should be noted that iron sulfide can be chemically oxidized in the absence of water, yielding ferrous sulfate and sulfur dioxide (Burke and Downs, 1938; U. S. Public Health, 1942), whereas this reaction in water yields ferrous sulfate and sulfuric acid (Frost and Streeter, 1924; Carpenter and Herndon, 1933; Trax, 1933; Herndon and Hodge, 1936; Hodge, 1938; Hoffert, 1947; Braley, 1951, 1954b; Leathen, 1953; Leathen, Braley, and McIntyre, 1953a).

Work leading to the supposition that biological factors enter into the breakdown of iron sulfide began with that of Winchell (1907) when he found that neither iron nor sulfur had gone into solution after a month's treatment of pyrite with aerated water. Sulfur in soil was shown to be oxidized by the microorganism *Thiobacillus thiooxidans* Waksman and Joffe (Waksman and Joffe, 1922). Powell and Parr (1919) found that at the end of a 90-day period inoculated coal samples showed a decided increase in soluble sulfur as compared to sterilized samples. The work of Carpenter and Herndon (1933) indicated that at least a part of the sulfate produced in acid-mine water can be attributed to bacterial action. This hypothesis was endorsed by Herndon and Hodge (1936) and Colmer and Hinkle (1947).

At the same time a second microorganism, *Thiobacillus ferrooxidans* Temple and Colmer, capable of oxidizing ferrous iron, was found by Colmer and Hinkle (1947) and, subsequently, by Leathen and Madison (1949), Colmer, Temple, and Hinkle (1950), Leathen and Braley (1950, 1951, 1952), Temple and Colmer (1951), Leathen (1953), Leathen, Braley, and McIntyre (1953a, b), and Braley (1954b). Various others have confirmed the occurrence of both organisms in acid-mine water, but denied that *Thiobacillus thiooxidans* takes part in the production of sulfuric acid, though indications are that *Thiobacillus ferrooxidans* increases the rate of oxidation of some forms of iron sulfide (Leathen and Madison, 1949; Leathen and Braley, 1950, 1951, 1952; Leathen, 1953; Leathen, Braley, and McIntyre, 1953a, b; Braley, 1954b).

Early investigations indicated the chemical breakdown of iron sulfide to be either impossible in the laboratory or extremely slow (Winchell, 1907; Carpenter and Herndon, 1933; Herndon and Hodge, 1936; U. S. Public Health, 1942); but by 1938, both moist oxidation (Hodge, 1938) and dry oxidation (Burke and Downs, 1938) had been accomplished.

The rate of oxidation of iron sulfide is apparently dependent upon: 1) oxygen concentration—the theoretical relationship between oxygen concentration and rate of acid formation is considered from a hypothetical standpoint in the U. S.

Public Health Bulletin (1942), but Braley (1951) presented data challenging this thesis; 2) moisture conditions—though it has been shown that oxidation can take place under dry conditions (Burke and Downs, 1938), the reaction is faster in water (Braley, 1951, 1954b; Leathen, Braley, and McIntyre, 1953a); 3) the type of iron sulfide—yellow pyrite, marcasite, or black amorphous pyrite—with a comparative rate of oxidation of 1.0, 9.6, and 81.8, respectively (Braley, 1954b); 4) surface exposed—piles of small particulate coal wastes, "bugdust" or "gob", are most active in producing sulfuric acid (Hodge, 1938); 5) microorganisms — though *Thiobacillus thiooxidans* apparently does not take part in producing sulfuric acid, the occurrence of the ferrous iron oxidizing microorganism, *Thiobacillus ferrooxidans,* may explain the increased rate of oxidation of natural acid-mine water over that of the acid sulfate salt water which was prepared in the laboratory and which did not contain this organism (Leathen and Braley, 1950, 1951, 1952; Leathen, 1953; Leathen, Braley, and McIntyre, 1953a, b), *i.e.,* complete oxidation in a few days naturally, as opposed to only 40 to 50% oxidation in 6 months in the laboratory (Braley, 1954b); and 6) Van't Hoff's Law, which applies, within limits, to both the biological and the chemical reactions.

There are two schools of thought as to the identity of the first products formed from the oxidation of iron sulfide and, therefore, under what conditions the reaction takes place. Most investigators believe that the first products are ferrous sulfate and sulfuric acid (Carpenter and Herndon, 1933; Trax, 1933; Herndon and Hodge, 1936; Hodge, 1938; Hoffert, 1947; Braley, 1951, 1954b; Leathen, 1953, Leathen, Braley, and McIntyre, 1953a), and, therefore, the reaction is one that includes water. There is, however, evidence that the end products are ferrous sulfate and sulfur dioxide (Burke and Downs, 1938; U. S. Public Health, 1942), thus indicating a reaction in the absence of water. Upon contact with water in the presence of oxygen, sulfur dioxide forms sulfuric acid.

Most workers are agreed that ferrous sulfate reacts with sulfuric acid in the presence of oxygen to form ferric sulfate and water (Carpenter and Herndon, 1933; Herndon and Hodge, 1936; Hodge, 1938; Braley, 1951, 1954b; Leathen, 1953; Leathen, Braley, and McIntyre, 1953a), and that the final reaction is the hydrolysis of ferric sulfate to ferric hydroxide and sulfuric acid (U. S. Public Health, 1942; Hoffert, 1947; Leathen, 1953; Leathen, Braley, and McIntyre, 1953a; Braley, 1954b). The reaction indicates that each molecule of iron sulfide forms two of sulfuric acid, which was demonstrated by Braley (1951, 1954b).

Until recently, no report had been given on the exact amounts of oxidized materials formed from a given amount of iron sulfide (Braley, 1954b). At the end of a 30-day experimental period, samples of yellow pyrite, marcasite, and black amorphous pyrite which had been placed in distilled water exposed to air had produced acid, as indicated by pH values of 3.81, 2.50, and 1.98, respectively, and grams of sulfate as

sulfite, 0.002, 0.0192, and 0.1636, respectively (Braley, 1954b).

Other ions associated with acid-mine water are calcium, magnesium, and aluminum (Braley, 1951; Parsons, 1955) and lead, copper, and zinc (Parsons, 1955).

Effects of Acid-Mine Water on Stream Chemistry

There are numerous accounts of stream beds being covered with a thick layer of reddish-brown iron oxides, "yellow boy" or "sulfur mud" (Frost and Streeter, 1924; Carpenter and Herndon, 1933; Trax, 1933; Herndon and Hodge, 1936; Hodge, 1938; Hoffert, 1947; Braley, 1951, 1954b; Leathen, 1953; Leathen, Braley, and McIntyre, 1953a).

Several authors have speculated as to what happens when a stream is polluted with mine water (Trax, 1933; Herndon and Hodge, 1936; Hoffert, 1947), but only Frost and Streeter proposed, as early as 1924, chemical reactions between acid-mine water and normal stream water. Recent works have been more productive, giving acid-alkaline reactions of acid-mine water polluting natural alkaline water, taking into account hydrolysis, oxidation-reduction, and buffering capacity of alkaline stream water (Braley, 1951, 1954c; Leathen, 1953; Leathen, Braley, and McIntyre, 1953a; Parsons, 1955; Cairns, 1957).

Effects of Acid-Mine Water on Stream Fauna

Under conditions of continuous acid-mine pollution, *i.e.*, effluents continuously present in the habitat, the complete destruction of fishes and other aquatic life is inevitable (Frost and Streeter, 1924; Carpenter and Herndon, 1933; Trax, 1933; Herndon and Hodge, 1936; Ellis, 1937; Hodge, 1938; Lackey, 1938, 1939; U. S. Public Health, 1942; Tarzwell and Gaufin, 1953). Although periodic fish kills attract much attention and some investigation of the fish kill and the toxic conditions of the stream (Frost and Streeter, 1924; Carpenter and Herndon, 1933; Trax, 1933; Herndon and Hodge, 1936; Ellis, 1937; U. S. Public Health, 1942), the number of reports which pertain to the occurrence of plankton and benthic organisms in acid-mine water in either streams or lakes is limited (Lackey, 1938, 1939, 1944; Crawford, 1942; Heaton, 1951; Parsons, 1955). The studies of Ellis (1937) and Anderson (1944) described the use of *Daphnia magna* Straus as a test animal for biological assay of various toxic materials. These experiments suggest the possible effects of ions found in acid-mine wastes on planktonic crustacea.

The effects of low pH upon the distribution of stream invertebrates and the composition of their communities have been given by many workers (Jewell, 1922; Carpenter, 1923, 1925, 1926, 1927a; Ellis, 1937; U. S. Public Health, 1942; Newton, 1944; Tarzwell and Gaufin, 1953).

Studies of the effects of metal salts of interest in this problem are limited to those on zinc, lead, copper, and iron. Though there are comparatively few works on lead and zinc, they are excellent studies (Carpenter, 1924, 1926; Reese, 1937;

Davies, 1938; Jones, 1938, 1940; Laurie and Jones, 1938; Newton, 1944; Hegsted, McKibbin, and Drinker, 1945). The published material on the effects of iron is limited to the oxides of iron and the effects of these precipitated on the stream bottom (Carpenter and Herndon, 1933; Herndon and Hodge, 1936; Lackey, 1938, 1939; U. S. Public Health, 1942; Newton, 1944; Braley, 1954c), and that of copper to Hegsted, McKibbin, and Drinker (1945).

Although there are many summaries and reviews of the literature which pertain to industrial wastes and their effects upon fishes (Suter and Moore, 1922; Belding, 1927; Ellis, 1937; Cole, 1941; Southgate, 1948; Doudoroff and Katz, 1950, 1953), there are no studies directly concerned with the specific combination of ions as found in acid-mine water or its effects upon fishes (Parsons, 1955).

Prolonged survival of various fresh-water fishes in acid water with a pH below 5.0 has been reported by several authors (Jewell, 1922; Jewell and Brown, 1924; Brown and Jewell, 1926; Carpenter, 1927b; Schäperclaus, 1927; Jones, 1939). When an acid produces a pH of 4.0 or less, it is toxic to fishes regardless of the acid or the acid-salt combination producing the acidity (Ellis, 1937). If concentrations less acid than pH 4.0 are considered, the toxic effect of the [kation (correction)] anion must be involved, for the toxicity at a given pH varies with the type of acid (Ellis, 1937; correction by Doudoroff and Katz, 1950). Therefore, neither acid intensity (pH) nor acidity (titratable acid) alone can be considered a reliable index of dangerous pollution (Doudoroff and Katz, 1953).

There are several suggestions as to the possible mechanism causing death to fishes: 1) coagulation or precipitation of mucus on the gill filaments resulting in anoxia (Carpenter, 1927b; Ellis, 1937; Westfall, 1945) or, since carbon dioxide and urea are excreted by the gills (Keys, 1937), it has been proposed that death may be due to accumulation of these wastes (Westfall, 1945); 2) decrease in the fish's ability to extract oxygen at the low oxygen tension in acid water (Shelford, 1923; Wiebe and McGavock, 1932; Townsend and Cheyne, 1944); and 3) inability of fishes to utilize oxygen at increased carbon dioxide tension (Fry and Black, 1938, 1939; Irving, Black, and Safford, 1939; Hart, 1945).

There are several metal salts of importance in acid-mine effluents (Ellis, 1937; U. S. Public Health, 1942; Braley, 1951; Calif. St. Water and Poll. Control Bd., 1953; Doudoroff and Katz, 1953; Parsons, 1955), and those considered in this type of study are discussed below.

It should be noted that the following conditions must be considered in the interpretation of the toxic effects of the metals as salts: 1) increased osmotic pressure—lethality of a physiologically unbalanced salt solution has been expressed by many authors, among them Garrey (1915, 1916), Heilbrum (1938), Baldwin (1949), and Ramsay (1952); 2) hydrolysis—release of the hydrogen ion from the water molecule by many metals is a fundamental chemical concept; 3) carbon dioxide tension—

increase in carbon dioxide tension resulting from the breakdown of the natural carbonates and bicarbonates affects fishes directly (Wells, 1913, 1915, 1918; Powers, 1922; Fry and Black, 1938, 1939; Irving, Black, and Safford, 1939; Hart, 1945; Doudoroff and Katz, 1953) or indirectly by tending to hold some of the metals in solution (Hogness and Johnson, 1947; Doudoroff and Katz, 1953); 4) oxygen tie-up—loss of dissolved oxygen to oxidizing salts is also a fundamental chemical concept; and 5) antagonism and synergism of metal cations—work showing distinct antagonism of metal ions has been published by Loeb and Wasteneys (1911, 1915), Garrey (1915), Powers (1920-21), Ellis and Ladner (1935), Ministry of Agriculture and Fisheries (1936, 1937), Ellis (1937), Jones (1938), and Young (1938), and synergism of the heavy metals is given by the work of Ellis (1937), Bandt (1946), and Doudoroff (1952).

There is a diversity of opinion as to the effect of the various forms of the aluminum ion upon fishes. Only the more exacting works are given here: 1) as a nitrate, 0.1 p.p.m. Al lethal (Jones, 1939); 2) as a sulfate, 7 p.p.m. Al lethal (Thomas, 1915) and 250 p.p.m. lethal (Sanborn, 1945); and 3) as potassium aluminum sulfate, 100 p.p.m. lethal (Ellis, 1937).

For most fresh-water fishes the lethal concentration of copper sulfate, as copper ion, is in the range of 0.1 to 5 p.p.m. (Marsh and Robinson, 1908; Kellerman, 1912; Belding, 1927; Catt, 1934; Smith, 1935, 1939; Ellis, 1937; Prescott, 1948). Somewhat higher concentrations of copper sulfate, up to 150 p.p.m., have been found to be harmless under conditions of high alkalinity (Wis. St. Bd. Health, 1939; Warrick, Wirth, and Van Horn, 1948).

Probably the most conflicting literature is that concerned with both ferrous and ferric ions of almost any salt. Both ferrous sulfate and ferric chloride are said to be toxic due to their acidity (Jones, 1939).

The range for ferric sulfate and chloride is given as from 1.00 to 100 p.p.m. of ferric ion (Clark and Adams, 1913; Ellis, 1937). Most workers have failed to state the pH values and, thus, their observations are of doubtful value (Clark and Adams, 1913; Powers, 1917; Carpenter, 1927b).

Work on ferrous compounds is subject to the same criticisms as those made of ferric compounds. From 50 to 130 p.p.m. of ferrous ion as a sulfate is toxic depending on alkalinity (Belding, 1927; Ellis, 1937; Sanborn, 1945). Again, the pH values were not given for much of the work (Clark and Adams, 1913; Belding, 1927; Carpenter, 1927b).

It has been demonstrated, in both distilled and natural water, that 0.1 to 0.4 p.p.m. Pb is toxic to fishes (Carpenter, 1925, 1927b; Jones, 1938; Newton, 1944). There is a great range in the reported lethal concentrations of lead: 10 p.p.m. (Rushton, 1922), 17 p.p.m. (Bodine, 1928), and 50 p.p.m. (Dawson, 1935). Although Carpenter (1925) failed to show cumulative poisoning of fishes in six weeks and longer in field and laboratory tests, catfish [sic] (brown bullhead, *Ameiurus nebulosus* (LeSueur) have been

shown to become anemic in 16-183 days (Dawson, 1935), and the cumulative poisoning effect was lethal to goldfish, *Carrassius auratus* (L.), after 61 days (Ellis, 1937).

Zinc compounds are toxic in concentrations of zinc ions as low as 0.01 p.p.m. (Affleck, 1952), 0.3 to 0.7 p.p.m. (Jones, 1938; Newton, 1944), and 0.5 to 1.0 p.p.m. (Jones, 1939; Rushton, 1949). There is little doubt that 5 to 15 p.p.m. is quite toxic to many species of fresh-water fishes (Abbott, 1924; Jones, 1935; Goodman, 1951).

Lead, zinc, and copper probably cause death in fishes by coagulation or precipitation of mucus secreted by the gills (Carpenter, 1924, 1925, 1926, 1927b, 1930; Ellis, 1937; Jones, 1938, 1939, 1947; Westfall, 1945) and subsequent anoxia or poisoning from metabolic wastes remaining in the blood stream.

Suspended forms of various hydroxides and oxides of iron clogging the gills have been offered as the explanation as to the offending form of iron and the mechanism of lethality under conditions of low hydrogen-ion concentration (Schäperclaus, 1933, 1941; Bandt, 1938, 1946; Schmidt-Nielsen, 1939; Sanborn, 1945; Kaemmerer and Erichsen, 1951).

Hypotheses as to effects of various salts of aluminum in the literature are wanting. Even the critical review of Doudoroff and Katz (1953) failed to uncover specific data on this metal.

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THE EFFECTS OF DROUGHT CONDITIONS ON THE FISH AND BOTTOM ORGANISMS OF TWO SMALL OXBOW PONDS

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Description of Area

Two oxbow ponds of Squaw Creek, located in Boone County, Iowa, were formed in 1952 when the stream was straightened in building a new bridge. The two oxbows are separated from the creek by an earthen fill and from each other by a road grade. Although there is no direct connection between the two ponds, they become united through overflow waters of Squaw Creek during flood periods.

The ponds are bordered by steep banks and wooded areas on the east and by wooded pastures on the west. Cattle use two areas of the south pond for watering. The north pond does not have watering areas easily accessible to the cattle.

The south pond normally has a surface area of approximately one acre and an average depth of three feet. The north pond normally has a surface area of two acres and an average depth of four feet. The water supply of these oxbows is maintained by run-off, seepage, and flooding from the creek.

The bottom deposits of both ponds are mainly of silt with sand and gravel in isolated areas. Many tree stumps and dead trunks are present in the north pond and the bottoms are covered with dead leaves.

The bulk of the fish population in the oxbows consisted of: carp, *Cyprinus carpio;* black bullheads, *Ameiurus m. melas;* bluntnose minnows, *Pimephales notatus;* and fathead minnows, *Pimephales p. promelas.* In addition, the following species were found: common white sucker, *Catostomus c. commersoni;* western golden shiner, *Notemigonus chrysoleucas auratus;* northern creek chub, *Semotilus a. atromaculatus;* central bigmouth shiner, *Notropis d. dorsalis;* stone cat, *Noturus flavus;* green sunfish, *Lepomis cyanellus;* orange-spotted sunfish, *Lepomis humilis;* white crappie, *Pomoxis annularis;* and central johnny darter, *Etheostoma n. nigrum.*

The water level in the creek was high enough to enter these ponds on July 14, 1955, and by July 19 the water levels had receded and the ponds were no longer connected with the creek. The south pond was rotenoned on July 19, eliminating all fish that had moved in from the creek during the flood. The bottom fauna in this pond was thus freed of predation by fish during the ensuing drought. Rains during July and August did not add enough water to the pond to raise the water level and by September the area was undergoing a severe drought.

Effect of Drought on the Bottom Fauna

Bottom organisms in the south pond were fairly abundant in November, 1954, but dropped off considerably during the summer probably due to the emergence of insects (Table 1). Rotenone treatment apparently did not affect the bottom fauna. The population on July 21, after treatment, was almost identical to that found July 18, before treatment. Furthermore, the samples of July 21 were picked without preservation and no dead bottom fauna organisms were found. By September 13 the area of the pond was much reduced and some of the sampling stations were no longer under water. By the first week in October the south pond was completely dry. The high population of bottom fauna per quarter-square foot in September is probably partly the normal fall increase in bottom fauna and partly the result of concentration of the organisms into a smaller area, without predation by fish.

Nematodes constituted a small part of the bottom fauna of the south pond. These worms were not taken in numbers large enough to draw conclusions concerning concentrations of the bottom fauna due to the drought.

Oligochaetes comprised 34.1% of the samples by number and 11.5% by volume. Concentration of oligochaetes during the drought was not observed. The average number per bottom sample was about the same before and during the drought.

Several clam shrimps (Order Conchostraca) were collected in the south pond during the second application of rotenone on May 28, 1955. Only one specimen was collected in the routine bottom sampling (June 3, 1955).

Two species of mayfly nymphs, *Hexagenia limbata* and *Leptophlebia* sp., were collected from the south pond during November, 1954. A large emergence of *Hexagenia limbata* occurred during May 24-26, 1955. On May 28, 1955, the pond was treated with rotenone. No mayfly nymphs were taken in bottom samples following treatment of the pond with rotenone. No dead mayfly nymphs were found, but the surface of the pond was literally covered with exuviae. In September, 1955, only three mayfly nymphs, *Leptophlebia* sp., were collected in the bottom samples.

Dragonfly nymphs were not taken in bottom samples from the south pond during the normal water levels, but the 7 bottom samples taken on September 13, 1955, during the drought contained 15 dragonfly nymphs (Family Libellulidae).

Concentration of bottom organisms due to the drought was best exhibited by chironomid larvae, ceratopogonid larvae, and *Chaoborus punctipennis*. Dipterous larvae constituted 50.3% by number of the samples collected during normal water levels and 92.4% by number of the samples collected during the drought. In September the south pond contained large numbers of *Notonecta undulata* (Family Notonectidae) and *Arctocorisa* sp. (Family Corixidae), making it impossible to collect a bottom sample that did not contain 20 to 30 notonectids and corixids. These forms were not counted or measured in the bottom fauna as recorded in Table 1.

TABLE 1.—Numbers and Volume of Bottom Fauna Organisms Collected in One-Fourth-Square-Foot Samples from the South Oxbow Pond, Boone County, Iowa.

Date	No. samples	No. organisms per sample			Volume in cubic centimeters		
		Mean	Standard deviation	Range	Mean	Standard deviation	Range
Nov. 9, 1954.....	10	98	65	24-232	0.64	0.76	0.01-2.30
Nov. 27, 1954.....	10	64	29	28-114	0.39	0.28	0.02-0.85
June 3, 1955.....	10	19	10	5-42	0.05	0.09	Trace-0.30
July 18, 1955.....	10	28	17	11-63	0.04	0.025	0.01-0.07
July 21, 1955.....	10	27	22	6-69	0.04	0.023	0.01-0.07
Sept. 13, 1955.....	7	208	85	116-365	0.97	0.69	0.26-2.11

Additional bottom samples were taken from areas of the south pond no longer under water on September 13, 1955. Samples of mud were collected to a depth of 12 inches. The mud samples were collected in layers approximately three inches thick and washed through a sieve to determine if the bottom fauna organisms had penetrated deeper into the mud. No macroscopic organisms were found in these samples. Within two weeks this pond was completely dry.

On November 9, 1955, a series of ten bottom samples were taken from the north pond. Each sample contained at least five leeches identified as *Epobdella* sp. On November 10 another series of ten bottom samples was taken. This group contained a total of five leeches. On November 11 no leeches were present in another series of bottom samples. Sampling to a depth of six inches in the mud failed to locate leeches.

Effects of Drought on the Fishes

The upper end of the north pond was dry by the latter part of September. Many fishes were trapped in drying isolated pools and soon died; fishes over 6.0 inches in total length were not found. The larger fish may have been taken earlier by predators which apparently abounded in the area as evidenced by the number of tracks of herons and raccoons.

By October 27, 1955, this 2-acre pond had been reduced to one large pool 150 by 20 feet with an average depth of 9 to 12 inches. The color of the water was black and the bottom mud had an oily odor. Large numbers of bullheads, fathead minnows, bluntnose minnows, and orange-spotted sunfish were gulping air at the surface of the pool. The dissolved oxygen content of the water at this time was 0.2 p.p.m. The dissolved oxygen content of this pool was again determined on October 31 and on November 8, and each time was found to be 0.2 p.p.m.

On November 8, 1955, the bottom of the north pond contained dead white suckers, creek chubs, bluntnose minnows, fathead minnows, bullheads, orange-spotted sunfish, and green sunfish. Two prostrated carp (15.0 inches, total length) were

retrieved from the surface of the pond. A thin ice cover which had formed on November 8, 1955, probably served to protect the dying fish from predators.

By November 8, 1955, some water was again present in the south pond and the water level of the north pond was no longer dropping. As the temperature dropped and evaporation ceased to be an important source of water loss, the water from small springs began entering the pond.

The concentration of fishes in the remaining water area on November 12 was so great that Ekman dredge samples collected from this pool all contained live bullheads. Some dead fishes were also taken in the bottom samples.

Winter Effects on the Drought-Shrunken Pond

By November 17 a three-inch ice cover had formed on the pond. Areas of thin ice near the bank and around logs contained large concentrations of minnows and bullheads. Continuation of the severe cold weather resulted in the formation of a six to nine inch ice-cover by November 28. Many of the fishes utilizing the small open areas around the logs were found with the lower halves of their bodies frozen in the ice and the upper halves exposed. The exposed halves of the bodies had been eaten away by predators, leaving the heads and backbones intact.

By December 28 the pond had completely frozen to the bottom and the bottom mud had frozen to a depth exceeding nine inches. Fishes were found frozen into the ice and the ice had a strong "fishy" smell due to decomposition of the fishes. The dark color of the bullheads absorbed heat and some decomposition was occurring even when the surrounding ice was solid.

Thirteen holes, approximately 18 by 18 inches, were cut and the fishes frozen into the ice were counted. The ice was arbitrarily marked off into three zones: upper two inches of ice, intermediate zone, and frozen bottom mud with the lower two inches of ice. No fishes were found frozen in the upper two inches of ice. In the intermediate zone 105 bullheads, 7 central bigmouth shiners, and 4 fathead minnows were found. In the lower zone 6 bigmouth shiners, 4 bluntnose minnows, and 25 fathead minnows were found.

Two possible explanations may be advanced to explain the presence of bullheads in the upper portions of the ice and the minnows in the lower portions of the ice and bottom muds. The minnows may have succumbed to the adverse conditions in the pond first and the ability of the bullheads to gulp air may have kept them near the ice until they were trapped there and frozen. A second explanation may be that the bullheads prevented the minnows from utilizing the area immediately under the ice.

Chironomid larvae were present in the frozen mud, and a sample of this mud was returned to the laboratory. Water was placed in the pail containing the frozen mud and it was allowed to thaw out to room temperature. All macroscopic bottom organisms in this sample of mud were dead.

Above-freezing temperatures during the last of February melted ice and snow, and by March 1, 1956, both oxbows were again completely

covered with 12 inches of water. Fifteen seine hauls made in the north pond contained no live fish, but a total of 55 dead fish were collected in the seine hauls—45 bullheads, 9 fathead minnows and 1 orange-spotted sunfish.

Eighteen bottom samples were taken in the north pond and ten bottom samples were taken in the south pond. No live macroscopic bottom forms were found.

Discussion

The destruction of the fish population and the macroscopic bottom fauna population of the two oxbow ponds apparently was complete.

Restocking of the two oxbows with fish is dependent on Squaw Creek overflowing into the ponds during the high-water periods and on fish survival in Squaw Creek. Preliminary spring field data collected from Squaw Creek indicate a low survival rate of fishes, but the extent of survival has not been determined.

The repopulation of the two oxbows by the bottom organisms will not be dependent on the overflow of Squaw Creek into the ponds, but will be dependent on the amount of survival of the bottom fauna in the creek. Most of the bottom fauna organisms have adult forms capable of repopulating the isolated pools.

Summary

Severe drought conditions in Boone County, Iowa, resulted in the complete drying of a 1-acre oxbow and in reducing a 2-acre oxbow to one large pool 150 by 20 feet.

As the water levels receded in the south pond a concentration of the bottom fauna, mainly dipterous larvae, was observed. By the latter part of September this pond was dry and the macroscopic bottom fauna was apparently destroyed.

As the water levels receded in the north pond many fishes were stranded in isolated pools and died when the isolated pools dried up. The remainder of the fish population was concentrated in the last remaining pool. Severe winter conditions resulted in the complete freezing of the pool resulting in the destruction of the fish population.

Bullheads were concentrated in the intermediate zone of the ice and the minnows were located in the lower two inches of ice and in the frozen bottom muds. Apparently all fishes and macroscopic bottom fauna organisms were killed.

Repopulation of the two oxbows by fishes and bottom fauna organisms will be dependent on the amount of survival of fishes and bottom organisms in Squaw Creek.

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BOTANY

UNIVERSITY OF ILLINOIS HERBARIUM, ITS HISTORY AND DEVELOPMENT SINCE 1868

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When the University of Illinois, then known as the Illinois Industrial University, was founded in 1868, Thomas Jonathan Burrill was appointed professor of natural history. It was under his direction that the University of Illinois Herbarium originated. In science courses in those days more emphasis was placed upon the collection and preservation of specimens and upon the arrangement of displays than at the present time. Logically, it followed that an herbarium—a collection of plant specimens for study—should develop.

Professor Burrill's collection of the flora of Champaign County, Illinois, made while he was superintendent of the Urbana public schools (1865-1868), formed the nucleus of the present herbarium. The only existing accession book (begun by Professor Trelease in 1923) states there were at that time 168,902 specimens in the herbarium. The majority of the specimens have been obtained by gift or by inter-institutional exchanges; however, there have been a few purchases, and collections have been made by members of the staff. At the present time the herbarium of the University of Illinois ranks fourth among the state university herbaria of the United States, being exceeded in number of accessions only by the universities of California, Michigan, and Minnesota.

The history of the herbarium may be divided into three eras—the first (1868-1912) was that of formation and early development under Professor Thomas Jonathan Burrill; the second (1912-1926) was one of organization under the influence of Professor William Trelease; the third (1939-) has been that of reorganization and modernization under the direction of Professor George Neville Jones.

Professor Burrill served the University of Illinois in various capacities from 1868 to 1912 from assistant professor to acting president. He gave the herbarium his personal collection which included some flowering plants of Champaign County, Illinois, but a greater number of the specimens were fungi. Not only are they the early collections of Burrill but also later, significant herbaria of his illustrious students, G. P. Clinton, F. S. Earle, A. B. Seymour, and M. B. Waite. It is due to the interest and influence of Burrill that an excellent collection of parasitic fungi has been accumulated. Tropical fungi from the Philippine Islands, Hawaii, and

Puerto Rico collected by Professor F. L. Stevens are contained in the herbarium.

The second period of development of the herbarium was effected under the direction of Professor William Trelease. Upon the retirement of Burrill in 1912, Trelease, who had achieved renown as the first director of the Missouri Botanical Garden, became professor of botany at the University of Illinois. During the time Trelease was at the university, exchanges of specimens were carried on with other institutions. By 1926 approximately 204,-628 specimens had been accessioned.

In 1939, when the present curator, Professor G. Neville Jones, joined the department of botany, it became his task to reorganize the herbarium according to modern standards. The collection is housed in 172 standard steel cases in two rooms and a corridor in the fireproof wing of the Natural History Building. Within the past ten years the floor space occupied and number of cases used have been doubled. This period has seen the building up of exchanges and inter-institutional loans among other botanical institutions of the United States and other parts of the world. The herbarium has become an important functional unit of the division of biology.

The University of Illinois Herbarium, now totalling more than 400,-000 specimens, is a good general collection. It is especially rich in representatives of the flora of the upper Mississippi Valley. Approximately one-fourth of the specimens are Illinois material which comprises the most nearly complete extant collection of Illinois plants, including many rare species and some possibly now extinct in Illinois. In addition to this material there is good representation of cultivated plants and of the European flora.

The University of Illinois Herbarium is the repository of some very fine early collections. Many of the specimens date back more than 100 years, but the greater number of them were collected less than 75 years ago. In addition to Burrill and his students, some of the other early collectors whose material or part of it is deposited here are: S. B. Mead, whose very important collection of 18,000 sheets was acquired in 1951; F. Brendel, collected about Peoria for 50 years; H. N. Patterson, collected in Henderson County, Illinois; and J. Schneck, collected in Wabash County, Illinois. Later collections at the university are those of: E. J. Hill, whose herbarium of 16,000 specimens, included 5,000 bryophytes, from the Chicago area and Indiana, Michigan, Minnesota, Mississippi, and New York; W. S. Moffatt, 11,000 specimens collected in the Chicago area; Robert Ridgway, who collected principally in Richland County, Illinois; and Mrs. Agnes Chase, whose early collections were from the northern part of the state and consisted largely of grasses collected before 1900. Some other valuable collections are those of: G. P. Clinton; G. H. French; F. C. Gates, principally in Champaign County; H. A. Gleason; Elihu Hall, an early collector in Fulton County; F. E. McDonald, near Peoria; H. S. Pepoon, Jo Daviess County; A. B. Seymour; George Vasey—an outstanding pioneer in Illinois botany and the first

curator of the United States National Herbarium—who collected in various parts of Illinois, but principally in McHenry County; M. B. Waite; and John Wolf, an associate of E. Hall. At present not more than half of Illinois' 102 counties have been thoroughly botanized. Contemporary collectors, Virginius H. Chase of Peoria, E. W. and G. B. Fell of Rockford, George D. Fuller of Chicago and Springfield, and G. N. Jones are making valuable contributions from various localities. Many present and former students, including R. A. Evers, G. P. Sivert, and G. W. Winterringer have contributed their plants.

The University of Illinois has recently purchased the 40,000 specimen herbarium of Virginius H. Chase (a nephew of Mrs. Agnes Chase) of Peoria Heights, Illinois. The Chase herbarium is the last of the larger private herbaria in Illinois not yet turned over to a university or museum and represents the residue of a much larger collection distributed through 50 years to several of the larger herbaria of the United States. About one-third of the specimens were collected in Illinois. The specimens are of exceptionally high quality and scientific value.

Today the University Herbarium furnishes reference material for research, serves as repository for type material entrusted to it, preserves data on original flora and vegetation, and provides material for study of geographical distribution of species. Moreover, it furnishes an identification service to the citizens of the state, whether scientists or amateurs. The facilities available offer opportunities for taxonomic research in almost all groups of plants.

PLANT FOSSILS FROM MANKATO TERRACE ALONG HUTCHINS CREEK, UNION COUNTY, ILLINOIS

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INTRODUCTION

Plant remains were discovered in 1954 in a terrace section along Hutchins Creek in Union County, Illinois, about four miles upstream from the junction with the Mississippi Valley (NW¼, SW¼, SW¼, sec. 25, T.11S., R3W.). The abundance of well preserved vegetation led to later sectioning and collection of material for paleobotanical study.

Hutchins Creek lies about 10 miles south of the farthest penetration of the Illinoisian ice. No direct glacial outwash materials reached its valley. However, the valley was repeatedly affected indirectly by alternating intervals of valley deepening and aggradation of the Mississippi Valley. During interglacial stages or stages of low sea level, the valley was greatly deepened. When sea level rose, or especially when great quantities of glacially derived material were brought down the master valleys, sediment choked the valleys and the valley floors rapidly aggraded.

Shaw (1915) recognized that such aggradation of the Mississippi, Ohio, and Wabash rivers caused ponding on the tributaries not themselves directly affected by outwash loads. Backwaters formed lakes of considerable extent in which stratified sediments accumulated. Recent studies by Leighton and Willman (1950) and by Harris (unpubl.) indicated a probable Tazewell and Mankato date for the principal terraces in southwestern Illinois. The Hutchins Creek terrace is considered to be of Mankato age because it does not have a cover of loess, and its surface lies about 15 feet above the flood plain.

Hutchins Creek has a flood plain about one-third of a mile wide in the vicinity of the terrace. Several segments remain, but the sediments are exposed only in the segment here discussed where Hutchins Creek impinges against it. The valley is bounded by steep valley walls incised by many short, steep tributaries. Bedrock is Devonian chert and silicified limestone mantled on the upland by loess.

The terrace sediments consist of materials similar to those now being transported by the modern stream. They are locally derived white chert pebbles and loess-derived silt. The terrace section consists of three zones: 3) poorly sorted alternating gravel and silt layers, 9 to 27 ft. deep; 2) well stratified silt and very fine sand layers, 2 to 9 ft.; and 1) basal gravel bed, 0 to 2 ft. below the surface.

MATERIALS AND METHODS

Sediment samples at approximately one-half foot intervals were taken for analyses, from one-half foot

above the gravel bed up to six and one-half feet. All of the sediment samples were from zone 2. Leaf fragments were treated according to the method of T. M. Harris (1932). Leaf cuticles of 40 species and varieties of southern Illinois mesophytic forest representatives were prepared in the same way. Samples for pollen and other spore analyses were prepared according to the methods of Erdtman (1954). Numerous slides of known pollen were prepared for aid in identification. References were made to keys and illustrations of Sears (1930), Wodehouse (1935), and Erdtman (1952, 1954).

Results

Examination of samples revealed the greatest abundance of fossils in the lower portion of zone 2. Where the section was measured there were two layers of leaves, branches, and other macro-fossils near the base in the gray silts. The following items were found: logs of the red-oak group; acorns and acorn cups similar to if not identical with those of *Quercus velutina,* black oak; portions of female cone scales of pine; leaf fragments of *Quercus, Fagus,* beech, *Tilia,* or basswood, a grass, and a fern. All of these were most abundant at about the 0.75 to 1.50-foot level above the coarse white gravel. Some fern leaf fragments were found as high as 1.75 feet above the gravel.

Beginning at the 0.5-foot level above the coarse white gravel a few *Quercus* and *Salix,* willow, and grass spores were identified. Just above, at about the 0.75-foot level, the most abundant numbers and kinds of spores were observed. *Pinus,* pine, appeared at this level only; *Quercus* appeared to decrease, whereas *Salix* increased slightly in number. Also noted were: *Carya,* hickory; *Liquidambar,* sweet gum; *Chenopodium,* pigweed; and a few *Compositae* grains. Fern spores were most abundant at this level, and at the approximately one-foot level. At the higher levels only a few grains of *Quercus* and *Salix* were found, and these disappeared at the six-foot level. Fungus spores were very abundant throughout all samples except those from the six-foot level which had no spores. Too few grains were found to make possible a pollen spectrum analysis.

Discussion and Summary

Although too few pollen grains were present to allow a percentage-wise comparison of certain value, there is perhaps significance in presence or absence of the types found at the various levels. Too few grains were found to give any clear indication of a forest sequence (Sears, 1948), except to note the appearance of some pine at the 0.75-foot level and its absence at all other levels. Oak and willow were found at all levels wherever any grains occurred. All forest-type pollen grains present are indicative for this region of a climate similar to that of the present. There appear to be two possible interpretations of the nature of the accumulation of organic debris: 1) essentially *in situ;* and 2) largely washed in by the stream which deposited the sediments. L. R. Wilson (pers. comm.) has suggested that the vegetation may represent a for-

est duff accumulation of a mesophytic forest floor because of the decomposed nature of the material, the comparative abundance of fungus spores, and the scarcity of pollen. On the other hand, the vegetation occurs in repeated and discontinuous layers, rather than in a single layer. Gravel layers occur above and below zone 2, and continual deposition is indicated. The seven-foot silt layer appears to represent a backwater deposit when the main channel was at a distance, and the plant remains were washed in during high waters. Later the channel shifted back to this site and successive bars and slack water silts rapidly accumulated. According to the second hypothesis, the plant remains are derived from the small Hutchins Creek basin, but not from the immediate area.

Acknowledgments

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NOTES ON THE ECOLOGY OF AMERICAN LOTUS IN SOUTHERN ILLINOIS

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Introduction

American lotus, *Nelumbo lutea* (Willd.) Pers., was selected as one of several aquatic plants to be used in experimental plantings in strip-mine ponds in southern Illinois. Fruits were scarified prior to planting and germinated in the laboratory as a control to field planting. Interest was aroused in the germination and ecology of these plants, and the following data resulted from experiments and observations completed subsequently.

The community studied is located in Crab Orchard Lake, five miles east of Carbondale, Illinois. Fruits for germination experiments were collected from Colp City Reservoir.

The American lotus commonly occurs from Florida to Texas, north locally to Ontario, Minnesota and Iowa (Fernald, 1950:641). A common inhabitant of quiet waters, it appears readily in artificial impoundments. Possessing a high degree of local dominance, it soon establishes pure stands in bays and estuaries. As areas completely covered by lotus are difficult to navigate, it is often considered a weed, and efforts have been made in some localities to eradicate the plant.

Martin and Uhler (1939:84) reported that the plant is of little or no use as waterfowl food, but rather, often chokes out valuable food plants.

Methods

As the dormancy of lotus is due to the impermeability of the ovary wall, any method of reducing this impermeability without harming the embryo will speed germination. Scarification by abrasion or cracking the ovary wall produces germination in a short time, but the results are not uniform. Immersion in concentrated sulfuric acid (H_2SO_4) proves to be the most feasible. Immersion in the acid for 2 hours is suitable, but fruits so treated require from 48 to 72 hours for initial germination whereas fruits treated for 5 hours germinate within 24 to 36 hours. Using 5 hours' immersion, germination success for a total of 300 fruits was 95%.

Fruits were weighed and volume measured every 2 hours for a 24-hour period to determine the rate of water absorption. Fruits were weighed on a single-beam laboratory balance, and volume was determined by a simple water displacement method. All figures for volume and weight were averaged from a sample of 100 fruits used in this experiment.

In the control experiment, 100 unscarified fruits were placed in water and measured daily for 15 days for volume and weight.

Seedlings were grown in the laboratory in a 10-gallon aquarium. Sand, under seven inches of water, was used in the aquarium.

In obtaining data in the field, 6 quadrats, each of 144 sq. ft., were used. To obtain annual productivity per acre, stalks were clipped at the rootstocks and air dried for three days.

Results

Germination and development.—Prior to germination, the fruit of American lotus is oval to spherical, rather uniform in size, averaging 12 mm. in breadth and 14 mm. in length. The average weight is 1.03 gms. and the average volume 0.837 ml. The specific gravity is 1.23. Hall and Penfound (1944:753) reported the water content of the cotyledons to be 7%. Following scarification the fruits no longer retained the oval appearance, but were distorted considerably. They were apparently as hard as before, however. The weight, volume, and specific gravity had changed but little (Table 1). When placed in water, all but a few fruits sank.

After 2 hours, 60% of the fruits were floating. All fruits remained distorted, some bearing little resemblance to their original form. The ovary wall was no longer hard and could be crushed easily by hand. Both weight and volume had increased considerably and continued to increase until germination (Table 1).

The rate of water absorption was most rapid during the first 2 hours (Fig. 1), gradually leveling off at the end of the 24-hour period. The distortion and swelling of the fruits resulted in an increase in volume that was proportionally greater than the increase in weight at the onset of water absorption. This resulted in a low specific gravity accompanied by floating and would provide a suitable method for the natural dispersion of the species.

After 24 hours, 5% of the fruits were beginning to split along the longitudinal axis. Although some of the fruits were (20%) still flaccid, the majority were fully turgid. Final measurements were taken at 24 hours. The fruits had swollen to 15 by 19.7 mm. The average amount of water imbibed during the 24-hour period was 0.934 gms.; the average volume increase was 1.003 mls. per fruit.

One hundred percent germination of the 100 fruits used in the experiment required 108 hours (Fig. 2). Average germinating time for the 100 fruits was 59.7 hours.

In the control experiment, neither volume or weight of the unscarified fruits changed during the period of 15 days (Table 2).

Ohga (1926:755) working with the Indian lotus, *N. nucifera,* the only other species in the genus, observed that the fruits were capable of germinating on oxygen-free media. Attempts to germinate *N. lutea* in oxygen-free media during this study yielded similar results. Ohga (*op. cit.*) found that the fruits of *N. nucifera* had an internal air pocket, containing 0.2 cc. of gas, 18.33% of which was oxygen, an amount sufficient for germination. *N. lutea* fruits possess a similar structure.

Ecology.—Adult plants are found on muddy banks a few inches above water level to a depth of more than six feet, although an ideal depth seems to be about three feet. Toward the interior of the community competition was all intraspecific.

TABLE 1.—Physical Reactions of Fruits of *Nelumbo lutea* to Acid Scarification.

Treatment	Av. wt., gms.	Av. vol., mls.	Specific gravity
none	1.03	0.84	1.23
A—Five hrs. in conc. H_2SO_4	0.96	0.83	1.16
B—Treatment A, plus 2 hrs. in wate	1.34	1.44	0.93
C—Treatment A, plus 4 hrs. in water	1.42	1.64	0.87
D—Treatment A, plus 6 hrs. in water	1.56	1.71	0.92
E—Treatment A, plus 8 hrs. in water	1.64	1.74	0.95
F—Treatment A, plus 10 hrs. in water	1.68	1.80	0.92
G—Treatment A, plus 12 hrs. in water	1.73	1.78	0.96
H—Treatment A, plus 14 hrs. in water	1.78	1.83	0.96
I—Treatment A, plus 16 hrs. in water	1.83	1.81	0.98
J—Treatment A, plus 18 hrs. in water	1.85	1.83	1.00
K—Treatment A, plus 20 hrs. in water	1.88	1.85	1.00
L—Treatment A, plus 22 hrs. in water	1.90	1.84	1.02
M—Treatment A, plus 24 hrs. in water	1.90	1.84	1.03

TABLE 2.—Comparison of the Original and Final Physical Measurements of the Fruits of *Nelumbo lutea.*

Treatment	Control		Experimental	
	Weight, gms.	Volume, ml.	Weight, gms.	Volume, ml.
none	1.03	0.87	1.03	0.84
Five hrs. in conc. H_2SO_4	omitted	omitted	0.86	0.83
Twenty-four hrs. in water	1.03	0.87	1.90	1.84
Fifteen days in water	1.03	0.87	100% ger	mination

Over 55,000 leaves per acre were determined in the community studied. Of these, 17% were erect. Erect leaves formed a large percentage of the total in the center of the community where intraspecific competition was most severe. Near the periphery of the community in deeper water, few or none of the leaves were erect. Even in aquaria, small leaves became erect when the surface of the water was covered by other leaves.

Leaves grew as large as 75 cm. in diameter, with an average diameter of 46 cm. (18.1 inches). The surface area of an average leaf was 1.78 square feet.

Foliage cover was 95% in the greater part of the community, decreasing around the periphery in deeper water. By the elevation of some leaves, and the overlapping of many of the surface leaves, a foliage area of 98,000 square feet per acre was obtained in the area studied. This was more than twice (2.25) the surface area of the water.

In late July, during the peak of the flowering season, 8,500 flower

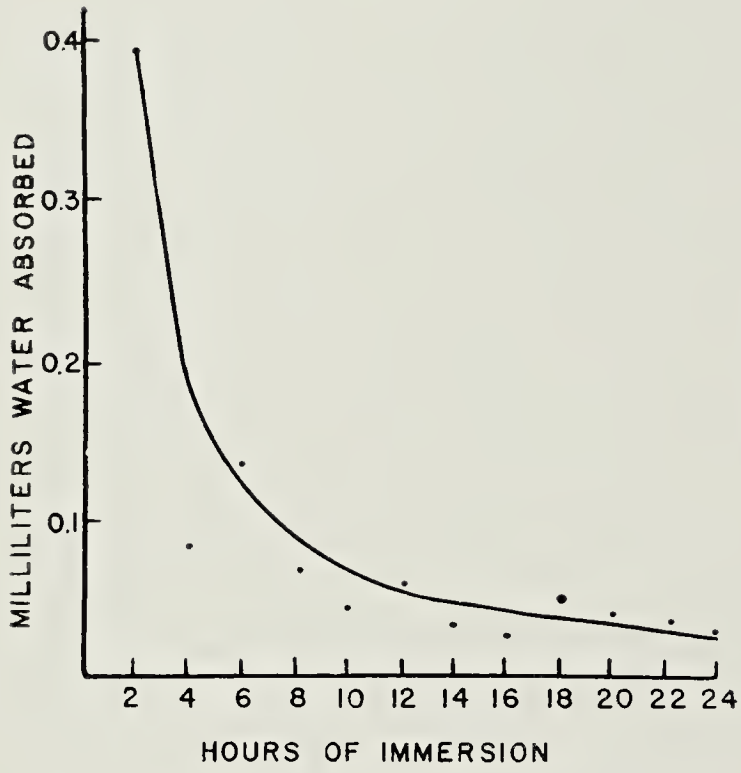

FIG. 1.—Amount of water absorbed by fruits of *Nelumbo lutea* during 24-hour period.

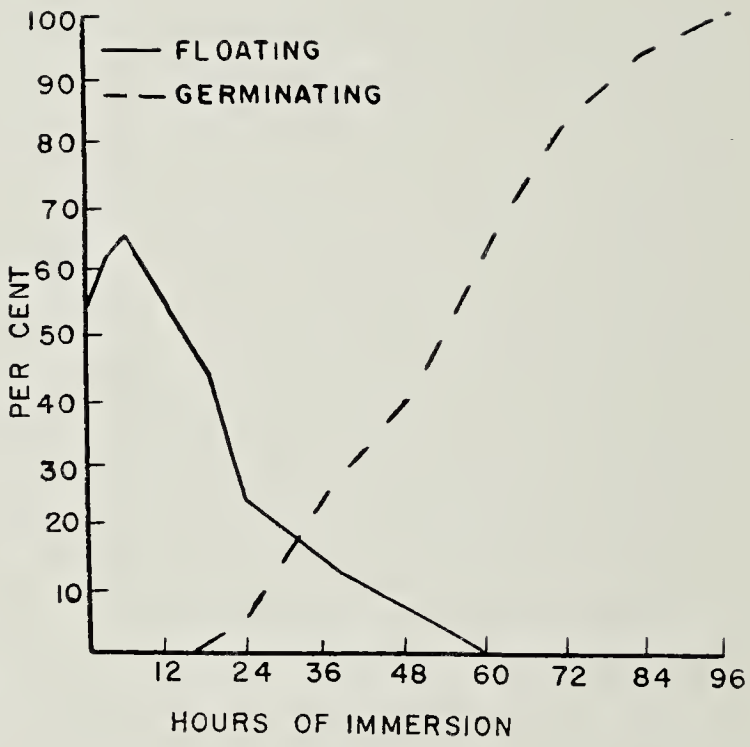

FIG. 2.—Comparison of germination rate of fruits of *Nelumbo lutea* to number floating, an indication of specific gravity.

stalks per acre were present, showing a 1 :6.5 ratio of flower stalks to leaves. With an average of 20 fruits per capsule, a production of nearly 200,000 fruits (almost 400 lbs.) would be realized per acre. As this was measured only once, in the latter part of July, and the plants produce flowers all season (although apparently at a lower rate toward the end of the season), the fruit production per acre could easily be as high as 500 to 600 lbs. Considering the fact that most of the reproduction in the communities is of a vegetative nature, the number of fruits successfully germinating and maturing in nature must be exceedingly low (Meyer, 1930 :225).

Cuttings in late July showed the annual productivity of vegetative material to be approximately 6.5 tons air-dry weight per acre. The rate of growth was so rapid, that after three weeks the areas that had been clipped were no longer distinguishable. The deposition of such large amounts of organic matter in the shallow, lentic habitats in which lotus grows should prove to be a great impetus to succession in these habitats. Although no efforts were made to study directly the importance of lotus in succession, the large annual productivity, as well as the slow rate of decomposition of the stems and leaves, would seem to indicate that the lotus plays an important part in this succession.

SUMMARY

1. Immersion of *N. lutea* fruits in concentrated H_2SO_4 for 5 hours was found to be the most feasible method of scarification, assuring initial germination within 24 to 35 hours, and yielding 95% germination.

2. Absorption of water by fruits is rapid at first, gradually tapering off until germination.

3. The average amount of water absorbed during the 24-hour period

following scarification was 0.934 gm. (90.7% of the dry fruit weight); the average volume increase was 1.003 mls. (119% of the dry fruit volume).

4. Fifty-five thousand leaves per acre were recorded, 17% of which were elevated; an average of 8,500 flowers per acre was determined, calculated to yield more than 400 lbs. of fruit per year.

5. An annual productivity of 6.5 tons air-dry weight per acre was calculated.

6. Lotus probably plays an important role in the succession of the areas in which it grows.

Acknowledgments

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GROWTH AND YIELD OF SINNISSIPPI FOREST STANDS

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INTRODUCTION

The goal of forest management is continuous production of forest products at an optimum level consistent with the related forest uses. Since the continuity and level of production rest upon the ability of the forest to grow, knowledge of the growth and yield of the various component stands of the forest is prerequisite to management. Of prime importance to foresters, this knowledge should be of considerable interest to all concerned with furthering the multiple-use concept which recognizes timber, wildlife, recreation, and watershed management as supplementary and interdependent phases of intelligent use and development of our forest resources.

Data on growth and yield are presently not available in sufficient numbers over a sufficiently broad base to enable reliable assessment of the productivity of our many and varied Illinois forest types. Furthermore, these meager growth data are based largely on increment cores. Growth data based on continuous inventory which provides for direct measurements of drain (including harvest and mortality), growth, and ingrowth, such as are presented here for Sinnissippi Forest, are almost nonexistent for Illinois forest types.

SINNISSIPPI FOREST

Sinnissippi Forest is a private enterprise of 2,313 acres (1954 inventory) operated to produce maximum, sustained, annual, net returns from growing, harvesting, utilization, and marketing of forest products. It is located in Ogle County, Illinois, a few miles south of Oregon on the Rock River, which bounds it on the north and west. The forest is favorably situated with respect to markets.

The beginning of Sinnissippi Forest management dates back to about 1905, when annual planting of some 50,000 white pine, *Pinus strobus,* was started by Frank O. Lowden. These plantings were continued until about 1917 (Dept. Forestry, Univ. Ill., 1953). Extensive fuelwood cuttings from the forest, beginning shortly after the turn of the century and extending to about 1945, removed principally dead and dying trees and those of low sawtimber value.

Reforestation activities were resumed in 1938 and have been carried on annually since that time. Livestock were excluded from the forest in 1938. A continuous inventory system was set up, and a systematic program of improvement cuttings was begun in 1949. Prior to this improvement program, almost no

commercial cuttings were made in the present sawtimber stands.

Forest Cover Types

Sinnissippi Forest is a part of the oak-hickory forest, the westernmost region of the eastern deciduous forest. Black oak, *Quercus velutina,* and white oak, *Quercus alba,* in pure or mixed stands predominate on the 1,577 acres of upland hardwood. Red oak, *Quercus rubra,* is generally found only on the better, more mesophytic sites. Pure stands of red oak, totaling 67 acres, are confined to coves and north-facing slopes. The upland oak stands are characteristically even-aged with the 71- to 90-year age-class predominant. Annual ring counts made in 1949 indicated that the majority of the trees in this age-class were then about 80 years old. Shagbark hickory, *Carya ovata,* although universally present in the forest, occurs infrequently in relatively undisturbed sawtimber stands, more frequently in more disturbed sawtimber stands, and abundantly in reproduction stands.

Mixed hardwood sawtimber stands, comprising only 54 acres of the upland forest, are composed principally, in approximate order of their occurrence, of: black and white oaks; American elm, *Ulmus americana;* black cherry, *Prunus serotina;* shagbark hickory; black walnut, *Juglans nigra;* and green ash, *Fraxinus pennsylvanica,* var. *subintegerrima.* Upland hardwoods areas, with a stocking of less than 1,200 board feet, are classed as hardwood reproduction. They total 306 acres which, for the most part, are former pasture.

The 71 acres of bottomland forest occurring as a narrow strip bordering the Rock River includes 61 acres of overmature, decadent stands of: silver maple, *Acer saccharinum;* American elm; a scattering of younger green ash; hackberry, *Celtis occidentalis;* and other bottomland tree species.

The 617 acres of forest plantations, including 74 acres of older white pine stands, are chiefly single-species plantings of white pine or red pine, *P. resinosa.*

A breakdown of the forest types by sites and 1949 age-class designations (miscellaneous stands and young plantations are excluded) is presented in Table 1A.

Field Measurements and Volume Computations

Field measurements for this study were obtained for the 1949 and 1954 forest inventories covering the 1949 through 1953 growing seasons on permanent, circular, one-fifth-acre, sample plots. Plots were laid out on a rectangular grid at the rate of 12 per 40 acres. Diameter measurements for trees 3.6 inches in diameter and over at breast height were available from both inventories. Diameters of trees over 8.5 inches were taken to the nearest one-tenth inch in such a manner that successive measurements of the same tree could be paired. Total and merchantable height measurements were available from two or more mechanically selected sample trees on each plot. Merchantability standards applied to the sample trees were in accord with sawtimber utilization practices at Sinnissippi Forest.

Merchantable lengths of hardwood trees were invariably limited by branching or deformity. Although a minimum top-diameter limit of eight inches was allowable, for hardwood sawlogs, this limit was seldom attained. Over 95% of the merchantable length determinations for hardwood trees 12 inches and larger on poor, medium, and good sites averaged 1, 1.25, and 1.5 logs, respectively, shorter than theoretical taper would allow to an eight-inch top. Merchantable length of white pine was determined entirely by taper to a six-inch top.

Stand tables were compiled, from the sample plot, field data sheets, by forest-condition classes consisting of stands of similar cover type, the same 20-year age-group, and site-quality classes. These groupings were made strictly in accordance with the forest-type map to avoid bias. Pure types were not recognized on the forest-type map unless 80% or more of the trees forming the dominant crown canopy were of the type species. Three upland, hardwood, site-quality classes—poor, medium, and good—corresponding to upland, oak, site index classes of 50, 60, and 70 (Schnur, 1937), respectively, were recognized. All pine plantings were considered to be on medium pine sites. Dominant trees in the oldest white pine planting have attained an average height of 67 feet at age 50. The silver maple-American elm type is considered to be on inherently good sites.

Basic volume computations were carried out in cubic feet by the volume-line method described by Spurr (1954). Least-squares solutions of the regression of sample-tree volume on diameter squared were computed for species within site classes. Sample-tree volumes were based on Table 3 in Gevorkiantz and Olsen (1955), giving gross, peeled volume of the entire stem in cubic feet. All hardwood volume-lines were based on measurements of sample trees in 1954 because no measurable change was observed in the diameter-height relationships during the five-year inventory period. Substantial changes in these relationships during the period were found in the case of pine, however; hence, separate volume-line solutions for 1949 and 1954 were computed and used for computing pine volumes. Good fits of the calculated regression lines with plotted data were obtained in all instances. Only slight adjustments of the hardwood regressions were required to correct for the observed curvilinearity below the ten-inch diameter class.

Gross board-foot volume estimates for trees 9.6 inches and larger were obtained from cubic-foot volumes using conversion formulae developed for Sinnissippi Forest inventory purposes. These formulae are based on the linear or essentially linear relationships existing between International one-fourth inch board-foot volumes and total cubic-foot volumes of sample trees as determined for the 1954 inventory. Sample-tree board-foot volumes were based on Table 2 of Gevorkiantz and Olsen (*op.cit.*). The influences of tree diameter and of site on this relationship were tested by co-variance methods and found not to be significant in the case of the data on upland hardwoods. Statistical differences found in the highly uniform

data on pines were small and considered of no practical significance. Consequently, pooled regressions of board-foot volume on total cubic-foot volume were computed by the least-squares method, one for upland hardwoods and one for pine. An approximate regression of board foot on cubic foot was used for the decadent bottomland, hardwood type, because gross board-foot volumes in this type are of little value since there is a large and variable amount of cull in sawtimber trees in this type.

The regression formulae used for converting total cubic-foot volumes of merchantable trees 9.6 inches and larger into board-foot volumes are the following where N is the number of trees making up the cubic-foot volume to be converted:

Upland hardwood

Bd. ft. vol. = 3.96 (cu. ft. vol.) — 18N

White pine

Bd. ft. vol. = 6.68 (cu. ft. vol.) — 20N

Bottomland

Bd. ft. vol. = 3.31 (cu. ft. vol.)

Results and Discussion

Inventory and growth data in cubic feet for all trees 3.6 inches in diameter and larger are presented in Table 1A, and in cubic feet and board feet for all trees 9.6 inches and larger exclusive of cull trees in Table 1B for the important condition-classes at Sinnissippi Forest. The values in Table 1B are of greatest interest in the management of even-aged stands nearing maturity, since they are most likely to contribute to yield during the current rotation. The cubic volumes of cull trees excluded from the 9.6-inch-and-over volume grouping amounted to: less than 5% for upland types on medium and good sites; up to 8% for upland types on poor sites with the exception of 18% for the 71- to 90-year-old black oak age-class; and 20% for the bottomland type of the total 1949 inventory volume in trees 9.6 inches and over. No cull white pine were recorded on the white pine sample plots.

Harvest volumes shown in Table 1A contained varying amounts of volume in cull trees girdled concurrently with the improvement cuttings. Dead trees harvested between inventories constituted less than 5% of volumes shown in Table 1B.

Mortality values are considerable, relative to growth, and must not be ignored, in a managed forest. Most of the mortality, being confined to smaller trees, might be expected as normal losses due to the suppression effects of the dominant trees. The abnormally high losses in trees 9.6 inches and larger, shown for the red oak type and the 71- to 90-year black oak and mixed oak age-classes on poor sites, reflect losses attributable to oak wilt disease. Oak wilt survey records at Sinnissippi Forest indicate that 55% of the mortality shown in Table 1A can be accounted for by the known recorded volumes of red and black oaks killed by oak wilt during a five-year period coinciding with the inventory period. The extremely heavy board-foot losses for the silver maple-American elm type are to be expected in overmature stands of this type.

Growth values appearing under the column headed "production," include ingrowth and growth on

TABLE 1A.—Volume and Growth Per Acre for Sinnissippi Forest Stands Based on 1949 and 1954 Forest Inventories. All Trees 3.6 Inches and Over in Diameter at Breast Height Included.

Condition class					1949 inventory	Periodic annual				1954 inven.
Type	Age class	Site quality	1954 acreage	No. of plots	Cu. ft.	Harvest	Mortality	Ingrowth	Production	Cu. ft.
						Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	
Upland hardwoods										
A. Red oak	71-90	Good	67.4	19	3,248	94	24	2	62	3,088
B. Mixed oak	71-90	Good	58.6	23	3,254	60	15	5	60	3,254
C. Mixed oak	51-70	Med.	23.6	6	2,096	77	16	1	28	1,847
D. White oak	71-90	Med.	111.8	35	2,487	39	9	1	40	2,494
E. Mixed oak	71-90	Med.	355.1	105	2,508	69	6	4	51	2,418
F. White Oak	91-100	Med.	6.4	3	2,624	0	5	0	34	2,792
G. Mixed hdwd.	Uneven	Med.	12.2	4	2,174	9	8	1	33	2,259
H. Black oak	51-70	Poor	12.5	4	1,853	99	8	0	35	1,536
I. Mixed oak	51-70	Poor	159.6	37	1,678	41	6	3	40	1,677
J. White oak	71-90	Poor	49.6	14	1,724	37	2	0	29	1,686
K. Black oak	71-90	Poor	195.2	51	1,709	33	10	4	45	1,766
L. Mixed oak	71-90	Poor	142.8	43	1,814	77	6	0	29	1,575
M. Mixed oak	Uneven	Poor	34.1	8	1,683	153	1	1	47	1,152
N. Mixed hdwd.	Uneven	Poor	41.7	11	1,704	2	7	10	56	1,974
O. Reproduction	1-30	.....	306.4	68	632	17	1	13	38	737
Bottomland hardwood										
P. Maple-elm	71+	Good	61.4	13	3,135	14	31	11	66	3,395
Pine plantations										
Q. White pine	45	Med.	15.7	5	3,080	54	3	0	155	3,582
R. White pine	31-40	Med.	8.6	3	2,120	4	0	0	151	2,853

TABLE 1B.—Volume and Growth Per Acre for Sinnissippi Forest Stands Based on 1949 and 1954 Forest Inventories. All Trees, Except Cull Trees, 9.6 Inches and Over in Diameter at Breast Height Included.

Condition class	1949 inventory		Periodic annual								1954 inventory	
			Harvest		Mortality		Ingrowth		Production			
	Cu. ft.	Bd. ft.	Cu. ft.	Bd. ft.	Cu. ft.	Bd. ft.	Cu. ft.	Bd. ft.	Cu. ft.	Bd. ft.	Cu. ft.	Bd. ft.
Upland hardwoods												
A	2,941	10,278	89	322	16	49	9	25	63	255	2,811	9,943
B	2,988	10,356	60	214	6	19	6	17	61	236	2,993	10,466
C	1,382	4,303	73	242	2	6	21	56	43	150	1,234	3,843
D	2,145	7,126	38	138	4	11	12	32	48	179	2,192	7,330
E	2,079	6,901	66	230	1	3	15	41	55	200	2,023	6,751
F	2,523	8,569	0	0	0	0	0	0	37	147	2,709	9,306
G	1,280	4,079	9	34	0	0	26	72	47	154	1,468	4,679
H	956	2,796	64	215	0	0	26	63	57	185	918	2,645
I	925	2,835	35	116	2	5	28	68	50	155	1,001	3,028
J	1,292	3,946	33	111	0	0	16	40	44	151	1,351	4,144
K	1,157	3,538	21	70	7	23	14	34	37	130	1,237	3,837
L	1,390	4,388	65	223	5	15	12	28	38	136	1,257	3,952
M	1,428	4,773	151	540	0	0	9	23	37	131	856	2,724
N	1,087	3,332	2	8	3	7	21	51	49	164	1,320	4,111
O	348	1,162	16	55	0	2	7	16	16	54	351	1,156
Bottomland hardwood												
P	2,391	7,412	13	41	29	91	9	27	34	104	2,493	7,728
Pine plantations												
Q	2,198	12,343	40	232	0	0	60	314	152	927	2,757	15,817
R	763	3,957	0	0	0	0	113	572	166	932	1,595	8,615

cut trees prior to cutting and exclude mortality. The effects of the recent improvement cuttings on these growth values are believed to be minor because volume was small and time short. Except for these effects, the values in Table 1A are indicative of growth for unmanaged stands. Periodic annual production for even-aged, oak, condition-classes and white pine stands is above estimated mean annual increment.

The total periodic production in trees 9.6 inches or more in diameter on the entire upland hardwood area, including reproduction stands, averaged 45 cubic feet or 160 board feet per acre annually. This production amounted to 95% of the periodic annual drain. Proper interpretation of the balance between production and drain depends on what is desired in stocking and age distribution.

Comparisons of yields as of the 1954 inventory (volume of periodic harvest plus 1954 inventory) among hardwood sites and white pine stands are of interest. The contrast between pine and hardwood yields is most striking when it is realized that the pine yields were obtained on dune sand of low fertility. White pine yields for the 50-year-old stand are comparable to cubic-foot, and surpass by 50% board-foot, yields for 80-year-old native hardwoods on the very best sites. Obviously, the comparison between pine yields and those of hardwood on the poor hardwood sites is more favorable to pine.

Conclusions and Summary

Conclusions based on a single inventory period as short as five years must be tentative; however, the following appear presently justifiable:

1. The total Sinnissippi Forest upland hardwood area of 1,577 acres is currently producing 250 thousand board feet of sawtimber in trees 9.6 inches or more in diameter annually (160 board feet per acre per year).
2. Approximately 55% of the cubic volume of mortality in trees 3.6 inches or more in diameter for the upland hardwood forest during the period 1949-54 was in black and red oaks killed by oak wilt.
3. Sawtimber yields of white pine stands on sandy soils on Sinnissippi Forest are expected to be at least twice those of native hardwood stands on good sites and at least five times those on poor sites over short rotations up to 80 years.
4. Hardwood sawtimber management on poor sites is unlikely to prove profitable because of low yields and generally poor quality of sawtimber trees. Conversion of these areas to white pine or other coniferous species offers greater management opportunities The growth and management opportunities for white pine at Sinnissippi Forest have been reported (Lorenz, 1952).

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THE RAVINE FLORA OF WINNEBAGO COUNTY, ILLINOIS

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The flora of southern Illinois ravines has attracted attention since the days of Engelmann, Forbes, Vasey, and Wolf and Hall (cited in Winterringer and Vestal, 1956). More recently, ravines and outcrops in other parts of Illinois have been written of by Pepoon (1909, 1917), Thorne (1924), Henderson (1929), and Stover (1930). The most recent, but confined entirely to the cliff-top habitats and plants of southern Illinois is the excellent, detailed report of Winterringer and Vestal (*op. cit.*). None of these studies applies to the plants of the dolomite ravines in the glaciated prairie area of northern Illinois. These are of sufficient interest to justify the following brief report.

In previous publications we have described the physiographic and climatic environment of Winnebago County, Illinois, in some detail (Fell, 1955; Fell and Fell, 1956). The plant names used in this article follow Jones (1950) with a few exceptions. The species mentioned are all represented by specimens in the Illinois State Museum Herbarium and for the most part also in the University of Illinois Herbarium and in the Evelyn I. Fernald Memorial Herbarium of Rockford College.

We are appreciative of the material help we have had from Dr. George D. Fuller and from Jean Voegeli of the Botany Department of Rockford College.

Considering the moderate topography of our prairie county we are well supplied with ravines that were made by streams eroding the glacial till and the underlying bed rock, which over most of the county is Galena or Platteville dolomite lying very near the surface. This dolomite is an inferior grade of limestone which occurs in thin or thick horizontal layers often with sand, chert or clay in the bedding seams. The ravines are of two types, the small ravines found on creeks over the county and the large river gorges. These two differ materially in the type of plants, though both provide various habitats for intraneous plants and furnish refuges for extraneous species.

Because the rock breaks easily with an irregular fracture the walls of the ravines are rough and broken, with numerous crevices, or step-like with minor shelves and recesses, often with an overhang, affording numerous lodging places for plants. Since the ravines are mostly on streams running east or west, a south-facing wall is exposed to direct sun and a north-facing wall is not exposed to direct sun. Either wall may be shaded by trees growing at the base of or on the face of the cliff. Other habitats in the ravines are the covering of the cliff

which slopes down to the edge of the dolomite forming the upper slope, the crest of the cliff, and the talus slope. The floor of the ravine is dolomite with a thin layer of bottom loam. Differences in exposure, soil, and moisture in various parts of the ravine determine the kind of plants which grow there and form a community that varies somewhat in its constituents on different outcrops but which follows a definite pattern. Much the same plants are found in all the small ravines in the county, but the species differ rather materially from those in the river gorges.

A Typical Small Creek Ravine

The outcrop on South Kinnikinnick Creek east of Roscoe, known as "South Ledges" furnishes a good example of the small creek ravine. A north cliff is in full sun most of the day and a south cliff is without direct sun and is partly shaded by trees that grow on the talus, at the base of the cliff, and on the much broken face which is cut by two small ravines. There is a definite overhang where the stream strikes the base of the cliff. The covering of the cliff, a thin layer of very sandy soil which is wind-borne, overlies glacial till of varying thickness so there is more or less of a slope from the general ground level to the edge of the dolomite without a bare ledge at the crest.

Plants of the upper slope of the south, unexposed wall.—The upper slope is densely wooded, a mixture of *Quercus alba* and *Q. velutina*, *Tilia americana*, *Juglans cinerea*, and *Ulmus americana* and *U. rubra* forming the canopy with an understory of *Carpinus caroliniana*, *Ostrya virginiana*, *Amelanchier* spp., and *Crataegus* spp. A tall shrub layer is well developed and includes *Cornus alternifolia*, several species of *Viburnum* (*V. lentago*, *V. rafinesquianum* and *V. acerifolium*), *Sambucus pubens*, and, farther back, *Prunus virginiana*, *Xanthoxylum americanum*, *Corylus americana*, *Rubus allegheniensis*, *R. strigosus*, and *Cornus racemosa*. Small shrubs are *Rubus hispidus*, *Ribes cynosbati*, and *Ceanothus americanus*. Vines are not abundant but one finds an occasional *Vitis vulpina* or *V. aestivalis*, *Parthenocissus* spp., and *Rhus radicans*. The forest floor is thickly covered with common spring-flowering plants and with many uncommon ones like *Chimaphilla corymbosa*, *Pyrola elliptica*, a small patch of *Pyrola secunda*, *Goodyera pubescens*, *Cypripedium parviflorum*, *Botrychium virginianum*, *B. multifidum* and *B. obliquum*, and *Dryopteris intermedia*. In shaded damp spots are *Trientalis borealis* and occasional patches of *Lycopodium lucidulum* and of *Carex deweyana*, while in more exposed places are *Pteridium latiusculum*, *Carex projecta*, and *Epilobium angustifolium*.

Plants of the south crest.—Here the sandy soil is a suitable place for *Juniperus virginiana* which grows 10 to 15 feet tall. Clothing the base of the junipers and draping over the edge of the cliff is an abundant growth of *Taxus canadensis*, in the shaded openings of which, on the crest, are such unusual plants as *Carex pedunculata*, *Corallorhiza maculata*, and *Mitchella repens*.

Plants of the south wall.—The face of the cliff, in its own shade.

is moist and, being rough, broken and fissured, offers many recesses for plants. These are either adventive like *Poa compressa* and common rock plants such as *Fragaria americana, Mitella diphylla,* and *Cystopteris fragilis* or such uncommon ones as *Actaea rubra, Aralia racemosa, Cryptogramma stelleri, Oryzopsis racemosa, Maianthemum canadense,* and *Polygonatum pubescens. Pellaea glabella* is not common on shaded cliffs, but when it does grow in damp shade it is much more robust.

The woody plants that grow on the lower part and foot of the cliff are, besides *Populus tremuloides,* such small trees as *Dirca palustris* and *Staphylea trifolia,* shrubs such as *Viburnum trilobum* and *Cornus rugosa,* and vines like *Lonicera dioica* and an occasional *Celastrus* or *Parthenocissus.* Other plants, each quite noticeable in its flowering season, are species of *Arabis* (*A. canadensis, A. laevigata* and *A. glabra*), *Anemone quinquefolia, Dentaria laciniata, Dicentra cucullaria,* and *Campanula intercedens.*

Plants of the south talus slope.—The sloping base of the cliff and the talus, with more moisture, are thickly covered in places with *Marchantia, Lunularia, Polytrichum,* and unidentified mosses. *Cystopteris bulbifera* grows in long rows in the wet cracks between the rock layers and festoons the damp walls of the overhang above the creek. Flat places are well occupied by *Camptosorus rhizophyllus* which is most common on large detached blocks of stone in the talus. The woodferns, *Dryopteris spinulosa* and *D. cristata,* are seen here more often than in the drier upland that *D. intermedia* prefers. Many of the plants of low woods are found here, *Hepatica acutiloba, Polemonium reptans, Arisaema dracontium,* and *Asarum acuminatum.*

Plants of the ravine floor.—The floor of the ravine is about 100 yards wide and contains, on a dolomite bottom, the small, clear, cold, rapid South Kinnikinnick Creek. *Cornus obliqua* borders the creek and gives it its name. The few trees, shrubs, and herbs include *Populus, Salix, Equisetum hyemale, Acorus calamus, Symplocarpus foetidus,* and *Iris shrevii.*

Plants of the exposed north wall.—The north wall of the ravine is a vertical cliff the height of its opposite, about 50 feet. The upper slope differs in being sparsely timbered with *Quercus alba, Q. velutina, Q. macrocarpa,* a few *Q. ellipsoidalis,* and some *Juglans nigra,* and *Carya ovata* and *C. cordiformis.* It has an oak-opening ground layer composed of such herbs as low panicums, *Danthonia spicata, Carex brevior, Hypoxis hirsuta, Arenaria lateriflora, Ranunculus fascicularis, Helianthemum* spp., *Lechea stricta, Scutellaria parvula,* and *Synthyris bullii.*

The crest has *Juniperus virginiana* and *Crataegus pruinosa,* but it lacks *Taxus canadensis* and other shade species. There is a sparse growth of *Carex pennsylvanica* along the edge, but the only conspicuous spring flower is *Penstemon pallidus.*

The face is largely bare. There are a few adventive grasses, *Cerastium vulgatum,* and an occasional *Asclepias verticillata,* but the important plant is *Pellaea glabella* which

grows preferably on the outer edge of an overhang, usually well up on the face, and is inclined to follow the soft bedding layers of the dolomite. The persistent fronds with their accumulation of dead leaves and cobwebs catch dust and falling particles, making suitable places for the growth of *Heuchera richardsonii, Arabis lyrata, A. pycnocarpa,* and *Arenaria stricta.* Nearer the base are *Epilobium adenocaulon, Aquilegia canadensis, Smilacina* spp., and others that need a little more moisture. The liverworts of the south wall are replaced here by lichens and fungi. The talus offers nothing distinctive.

Other Small Ravines

A.—"North Ledges" on North Kinnikinnick Creek has many of the same plants but lacks some of the northern species. *Pellaea glabella* and other ferns are particularly noticeable. The wide floor provides more space for wet-ground plants like *Spartina pectinata, Scirpus* spp., *Juncus* spp., *Mimulus ringens,* and *Aster puniceus.*

B.—Hall Creek "Dells' has a few residual white pine trees on the crest of the cliff. Yew grows here as does also *Ribes hirtellum, Aralia racemosa, Gentiana quinquefolia, Myosotis scorpioides,* and *Aster furcatus.* Here are *Cryptogramma stelleri,* a minute fern that is hard to find because of its size and because it fruits early and disappears, and *Carex pedunculata* which is equally difficult because all sign of fruit is gone by the middle of May. *Mertensia virginica* thickly covers a large area of the floor.

C.—Seward Bluffs on Grove Creek also has an exposed and an unexposed cliff. On the crest of the latter are *Botrychium obliquum, Carex pedunculata,* and *Cornus rugosa.* In the stream are *Callitriche heterophylla* and species of *Potamogeton.* On the creek bank we re-discovered *Geranium sibericum* whose presence was commented upon by M. S. Bebb three quarters of a century ago.

D.—The Rock Cut outcrop in the Forest Preserve on Willow Creek is unusual in the tall spur of dolomite which, on its exposed face, is clothed with *Pellaea glabella* which gives way to *Camptosorus rhizophyllus* on its shaded base. Here is an unusual number of ferns and such uncommon plants as *Vicia caroliniana* and *Viola affinis.*

Besides these there are some minor ravines and shaded dolomite outcrops having similar plants—in Tullock woods northwest of Rockford, in Kishwaukee River Forest Preserve, and on Kent Creek at the Illinois Central Railroad station in Rockford.

In the high central part of the county in Burritt and Owen townships are a few dry ravines made by streams which have long since disappeared. The walls of some of these are sloping enough to assume the character of hill-side "limestone prairies" with *Andropogon scoparius, Bouteloua curtipendula,* and *Sporobolus* spp. A good example of this is on Owen Center Road near Roscoe Road. Another stranded ravine on Illinois Route 70 not far from Meridian Road has been so persistently pastured that none of the original flora is left.

The River Gorges

When the glacier or its deposits blocked the large rivers in the south part of the county, the rivers were forced to seek new channels. Rock River moved to the west and cut a new bed in the dolomite. Evidence of this is seen at Blackhawk Park in Rockford and at the McCormick cliffs in Ogle County. Suggestions of a ravine flora are seen in *Dirca palustris* in Blackhawk Park and the ferns on the rocky opposite bank, but the gorge of Rock River is not well enough marked to make a floristic study feasible.

Kishwaukee River Gorge.—In preglacial times Kishwaukee River continued south from the forest preserve. When its channel was blocked by the glacier, the river turned sharply west and cut a new channel 3 miles long and 150 feet deep through the level till and the underlying dolomite to make a new outlet into Rock River below New Milford. The river is at the 700-foot level at the middle of the gorge where it is 100 feet wide. From crest to crest at this point the gorge is one-half mile wide. At only a few places does the depth of the river exceed three feet, the bed being dolomite or gravel on dolomite. The floor of the gorge, the flood plain of the river, is for the most part less than 100 yards wide. The slope of the walls of the gorge is abrupt from the floor for about 100 feet. These steep walls are much broken, there being numerous small ravines, some of them mere crevices a few feet wide, in which ice and packed snow stay until long after the flowering of hepatica. The rounded crowns of the walls are till-covered and slope back gradually north and south to flat ground at the 850-foot elevation. The forest strip was formerly one-half mile wide on each side of the river but is now confined to the gorge where it is comparatively undisturbed. North and south of the forest strip is level prairie.

The trees of the gorge are more mesophytic than over the county as a whole. *Quercus velutina* and *Carya ovata* do not dominate, there being a larger proportion of *Quercus alba, Q. ellipsoidalis, Q. muhlenbergii,* and *Q. rubra* than is usual in this area. *Platanus occidentalis* and *Gymnocladus dioica* are more frequent here than elsewhere in the county. On the flood-plain are the common bottom-land trees, *Acer saccharinum,* (but no *A. rubrum*), *Tilia americana, Ulmus,* some *Acer saccharum,* and *Fraxinus quadrangulata* which is uncommon with us. The under-story is more distinct on the shaded south wall than elsewhere, the species being *Carpinus caroliniana, Ostrya virginiana, Euonymus atropurpureus, Staphylea trifolia, Ptelea trifoliata, Crataegus succulenta,* and *C. pedicellata* near the river and *C. pruinosa* and *C. punctata* on the crown. Juniper is less common than on Rock River and in the little ravines. Other secondary trees are *Populus grandidentata, Gleditsia triacanthos,* and *Amelanchier canadensis* and *A. laevis.*

The forest that covers the crown is more open. *Quercus* spp., *Carya* spp., *Juglans nigra, Fraxinus* spp., and *Celtis occidentalis* are the more common trees.

The shrubs of the river bank and

talus are: *Cornus alternifolia,* often of a definitely pagoda form; *Cornus rugosa* which, though a northern shrub, often suffers from late frosts; *Cornus obliqua* on the river bank where *Rosa palustris* is also found; *Sambucus canadensis;* and *Viburnum lentago.* In a minor ravine is the only *Hamamelis virginiana* that we have seen in the county. On both crowns is *Rhus arenaria* which seems to be only on Kishwaukee River in this county. The predominating gooseberry is *Ribes missouriensis,* and the common tall blackberry is *Rubus alligheniensis. Rhus glabra* and *Cornus racemosa* occur in patches, and *Ceanothus americanus* and *Amelanchier spicata* are occasional. The vines are *Vitis riparia,* often of large size, *Celastrus scandens,* and *Parthenocissus,* often in thick tangles.

The herbs of the flood-plain are those of the mesophytic woods of this area, there being no prairie species. Unusual plants of the river bank are *Carex davisii, Napaea dioica, Cassia hebecarpa, Amorpha fruticosa, Stellaria aquatica,* and *Dasistoma macrophylla.* The talus and lower part of the shaded wall harbor such unusual species as *Jeffersonia diphylla, Habenaria bracteata, Orchis spectabilis,* and *Cypripedium parviflorum.* Below the crown and in some of the little ravines are *Hepatica americana, H. acutiloba,* and plants which appear to be hybrids of these. On the crown are *Euphorbia commutata, Polygala verticillata, Gentiana quinquefolia, Pyrola elliptica,* and *Goodyera pubescens. Amphicarpa* forms a thick carpet in the upper part of some ravines.

The exposed north wall is thickly wooded with the same trees that cover the crown and thus, being in rather dense shade, there is not the marked difference in herbs that is found in the small creek ravines. On this wall liverworts and mosses which are abundant on the south wall are replaced by lichens. An unusual finding on this crest is *Orobanche uniflora.*

Because of the rugged terrain and the variety of habitats, especially cool, damp, shady places, the gorge has an unusually large fern flora. On the crown and above it is *Pteridium latiusculum* in large patches and, usually at the upper end of a small ravine, *Dryopteris intermedia* and *Adiantum pedatum.* Below the crown in exposed places is *Pellaea glabella,* though not as abundant as on many small outcrops. Farther down on sheltered shelves is the uncommon *Woodsia obtusa* and the more uncommon *Polypodium virginianum.* Toward the upper end of many ravines and in shady nooks on the face of the cliff is a luxuriant growth of *Cystopteris fragilis,* and in damper places on rock and on soil in the bottom of little ravines is the most vigorous growth of *Cystopteris bulbifera* that we have seen. *Camptosorus rhizophyllus* is rather common and in a small ravine near Camp Rotary is a large colony that has tail-less fronds. We did not find any that lacked basal lobes. On the talus is *Osmunda claytoniana, Dryopteris spinulosa,* and very infrequently *Dryopteris cristata* and *Athyrium thelypterioides. Athyrium angustum* and *Onoclea sensibilis* are in the bottom woods as is *Botrychium virginianum.* The evergreen

grape-ferns are on higher ground.

We have not tried to name all the plants that grow in the ravines, our purpose being mainly to show that the outcrops furnish living quarters for many species that would otherwise be absent from the county. Particularly in the small creek ravines, many of the plants are northern species which are uncommon this far south: *Pinus strobus, Taxus canadensis, Cryptogramma stelleri, Carex pedunculata, C. deweyana, Pyrola secunda, Epilobium angustifolium, Viburnum trilobum,* and many others. Whether their being here now is due to their being remnants of a more widespread distribution following the retreat of the glacier, or to their chance finding of a suitable environment is not apparent. Nor is it clear why the small creek ravines have such a large number and a greater proportion of northern species than the large Kishwaukee River Gorge has. Equally unexplained is the presence of some southern species — *Carex davisii, Gymnocladus dioica, Amorpha fruticosa, Fraxinus quadrangulata,* and *Dasistoma macrophylla* — in Kishwaukee River Gorge and their absence from the small creek ravines.

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MODIFICATION OF ZEIN BY DEAMIDATION

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Zein, the alcohol-soluble protein of corn, is insoluble in water below pH 11. Its solubility in aqueous alkali at pH 11.3 to 12.5 is due to the formation of sodium salt of the tyrosine hydroxyls (Croston, Evans and Smith, 1945). The calculated molecular weight from amino acid analysis is 25,190 (Cardinal and Hedrick, 1947), but the observed molecular weight may be greater depending upon the degree of polymerization caused by the formation of disulfide bonds between molecules (Laine, 1944). Pure zein contains 16.2% nitrogen, of which 36% is in the form of asparagine and glutamine—the monoamides of aspartic and glutamic acids. Thus, the non-peptide amide content (-$CONH_2$) is 0.206 equivalents per 100 gms. of zein, and this amide nitrogen accounts for 18% of the total nitrogen (Cardinal and Hedrick, 1947).

The insolubility of zein in water at neutral pH has been attributed to the absence of carboxyl groups. Gortner and Gortner (1949:328) have pointed out that it should theoretically be possible to prepare highly acidic proteins by splitting off the ammonia from the non-peptide amide groups and thus leaving the peptide linkages practically unaltered. They treated gliadin with dilute phosphoric acid under pressure and hydrolyzed as much as 96% of the non-peptide amide groups with only 6% of the peptide bonds being broken. Virtanen and Hamberg (1947) and Laine (1944) have shown that the non-peptide amide groups of zein are hydrolyzed more than three times as fast at pH 1.5-1.8 and 37° C. as the peptide bonds.

Steinhardt and Fugitt (1942) used detergents, such as dodecylsulfonic acid, to deamidate egg white and wool. However, we were unsuccessful in applying their technique to zein because of the difficulty in removing the large amount of detergent from the reaction product. Shildneck (1942) treated corn gluten with acid, solubilized both the starch and protein and then precipitated the protein by adjusting the pH to 4.5. This degraded protein was reported to be more soluble in aqueous alkali than before hydrolytic treatment. Cleland and Henke (1951) hydrolyzed corn gluten with lime at 25 to 45 p.s.i. steam pressure and precipitated the protein material by adjusting the pH to 4.5 to separate it from the solubilized starch. The resultant protein could be dissolved in aqueous alcohol.

This paper reports the preparation and some of the properties of partially deamidated zein which retains most of its molecular size.

Materials and Methods

Commercial zein containing 15.6% nitrogen, 0.3% ash, 0.6% carbohydrates, and 1.0% oil was used

in this study. Nitrogen analysis indicated a purity of 96%.

The rate of ammonia liberation was determined by placing 5 gms. of zein and 100 mls. of water containing the alkali in a flask equipped with a reflux condenser leading into boric acid solution containing bromcresol green and methyl red to absorb the ammonia. The reaction mixture was held at reflux temperature, and washed air was bubbled through the mixture to remove the ammonia. The boric acid solution was titrated at intervals as described by Croston (1943:13-15).

The conditions used for preparing deamidated zein are shown in Table 1. It was necessary to chill the mixture of water (or water-ethanol) and hydrolyzing agent before adding the zein to prevent formation of a gummy mass. The reaction flask was fitted with a reflux condenser and heated for the time and at the temperature shown in Table 1. The product was isolated by adjusting the pH to 7.0, centrifuging when necessary to clarify, adjusting the pH to 4.0 and centrifuging to remove the precipitate. The precipitate was washed with water, dissolved by adjusting the pH to 7.0 with sodium hydroxide, and dialyzed until free of salts. The dialyzer contents were then either lyophilized or evaporated to dryness under reduced pressure.

Results

The rate of ammonia liberation from a 5% aqueous dispersion of zein at reflux temperature with 4 different levels of sodium hydroxide is shown in Figure 1, where 0.25 mole of sodium hydroxide is sufficient to disperse the zein and account for the primary amide groups in 100 gms. In Figure 2 the rate of ammonia liberation with barium hydroxide at two levels is compared with that for calcium hydroxide at two levels.

Table 1.—Preparation of Water-Soluble Zein.

Prep. No.	Ratio H_2O:zein	Agent used	Moles agent	Temp., °C.	Time, hrs.	Yield, percent	$-CONH_2$ hydrol., percent
1.....	10:1	NaOH	0.25	75	8	46	..
2.....	1:1	NaOH	0.25	80	1	29	..
3.....	30:1	$Ca(OH)_2$	0.535	60	40	20[2]	88
4.....	10:1[3]	$Ca(OH)_2$	0.10[4]	100	4	33	..
5.....	1:1	$Ca(OH)_2$	0.13	100	1	33	..
6.....	1:1	$Ba(OH)_2$	0.13	100	1	40	..
7.....	14:1[3]	$Ba(OH)_2$	0.625[4]	100	½	45	57
8.....	10:1	$Sr(OH)_2$	0.625[4]	100	½	50[5]	25
9.....	10·1	HCl	0.214	80	16	50	54

[1] Based on 100 gms. starting zein, dry basis. 100 gms. of commercial zein contained 0.20 equivalents of primary amide groups, and 0.05 equivalent of alkali was required to dissolve zein.
[2] Soluble in water at pH 5.5.
[3] 30% aqueous ethanol used as solvent.
[4] Zein dissolved in 0.05 mole NaOH before alkaline earth hydroxide was added.
[5] Cloudy solution at pH 7.0; soluble at pH 8.0.

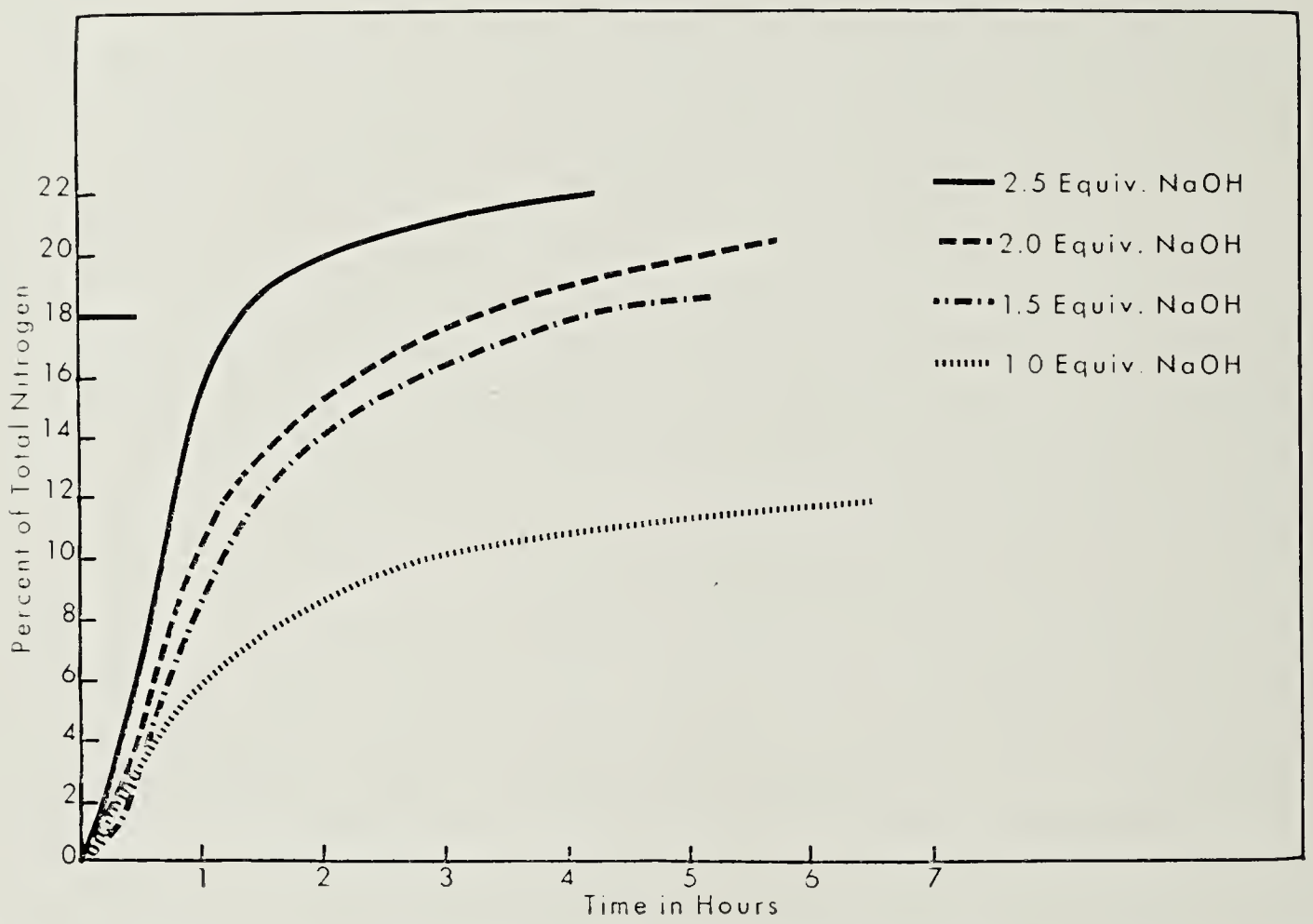


FIG. 1.—Rate of NH_3 liberation from zein by different equivalents of NaOH based on non-peptide amide groups.

The hydrolytic conditions used for preparing water-soluble zein are shown in Table 1. The moles of agent used are based on 100 gms. of zein which contains 0.20 equivalent of non-peptide amide groups ($-CONH_2$), and 0.05 equivalent of alkali is used up in dispersing the zein before hydrolysis (Cardinal and Hedrick, 1947; Croston, *et al.*, 1945). Thus, approximately 0.25 equivalent of alkali per 100 gms. of zein is required to hydrolyze the non-peptide amide groups on an equivalent basis. The percentage of total non-peptide amide groups hydrolyzed to carboxyl groups was calculated from the difference in total nitrogen content before and after hydrolytic treatment.

The ultracentrifuge patterns of zein and deamidated zein are compared in Figure 3.

Discussion

Prolonged boiling of zein with strong alkali, as illustrated in Figures 1 and 2, results in considerable loss of ammonia by deamination, in addition to the deamidation as has been shown to occur for other proteins (Croston, 1943). Since the non-peptide amide nitrogen of zein is 18% of the total nitrogen, a reaction time of 1 hour or less is indicated for hydrolysis of these amide groups with strong alkali at reflux temperature. The lower curve of Figure 1 indicates that about one-half of these amide groups may be hydrolyzed by an equivalent amount of sodium hydroxide. The lower curve of Figure 2 indicates that increasing the amount of lime does not increase the rate of ammonia liberation, probably because of the relative insolubility of lime.

All of the preparations listed in Table 1, except No. 8, were soluble in water at pH 6 to 7. No. 8 gave a slightly cloudy dispersion at pH 7.0, but gave a clear dispersion at pH 8.0. From the data shown in the last column, it appears that zein becomes soluble in aqueous solution at pH 6 to 7 when about 40% of the non-peptide amide groups are hydrolyzed to carboxyl groups. Mecham and Olcott (1947) reported that soybean protein (16.0% total nitrogen) contains 0.114 mole of amide nitrogen (10% of the total nitrogen). According to Drackett (1955) there are 0.183 mole of dicarboxylic acids per 100 gms. in soybean protein. Calculations show that 38% of the dicarboxylic acids in this protein exist as free-carboxyl groups to which its solubility in mild alkali is attributed. Preparation No. 3, where 88% of the non-peptide amide groups were hydrolyzed, was soluble at pH 5.5. All of these preparations precipitated when the pH was adjusted to 4.0 and could be recovered by centrifugation. Whether the yield of high molecular weight, water-soluble zein can be increased is a matter of further research.

Hydrolysis with lime always resulted in denaturation or insolubilization of a portion of the zein. This denaturation is attributed to splitting out ammonia between non-peptide amide groups of adjacent molecules to form secondary amide linkages and thereby cross-linking to form 3-dimensional polymers: (pr= protein)

$$\text{Pr-CO-NH}_2 + \text{NH}_2\text{-CO-PR} \xrightarrow{-\text{NH}_3} \text{Pr-CO-NH-CO-Pr}$$

This type of a reaction is known to occur with polyacrylamide (Minsk and Kenyon, 1949), and the irreversible insolubilization of zein can also be explained on this basis. Undoubtedly, the formation of secondary amide cross-links is involved in the heat denaturation of most proteins. In the present study, insolubilization was not observed when strong alkalies were used, probably because the secondary amide linkages were hydrolyzed by the more drastic conditions.

Figure 3 compares the ultracentrifuge patterns of zein and the deamidated zein. From the sedimentation constant, the molecular weight is estimated at about 20,000 and the molecular size appears to be fairly uniform, considering the method of fractionation. Light-scattering measurements gave molecular weights of 17,000 to 20,000. Electrophoretic patterns showed a great deal of variance in the number of carboxyl groups on different molecules.

Solutions of the deamidated zein preparations showed no tendency to gel even at 30% concentrations. The aqueous solutions could be whipped into a meringue, and deamidated zein was successfully substituted for egg white in a recipe to make marshmallows. Five grams of Preparation No. 5 were dissolved in 75 mls. of water, 10 gms. of peanut oil added, and the mixture whipped into a stable emulsion. A 7% isotonic salt solution of Preparation No. 3 was repeatedly injected intravenously into rabbits and guinea pigs without any apparent toxic effects (Bollman,

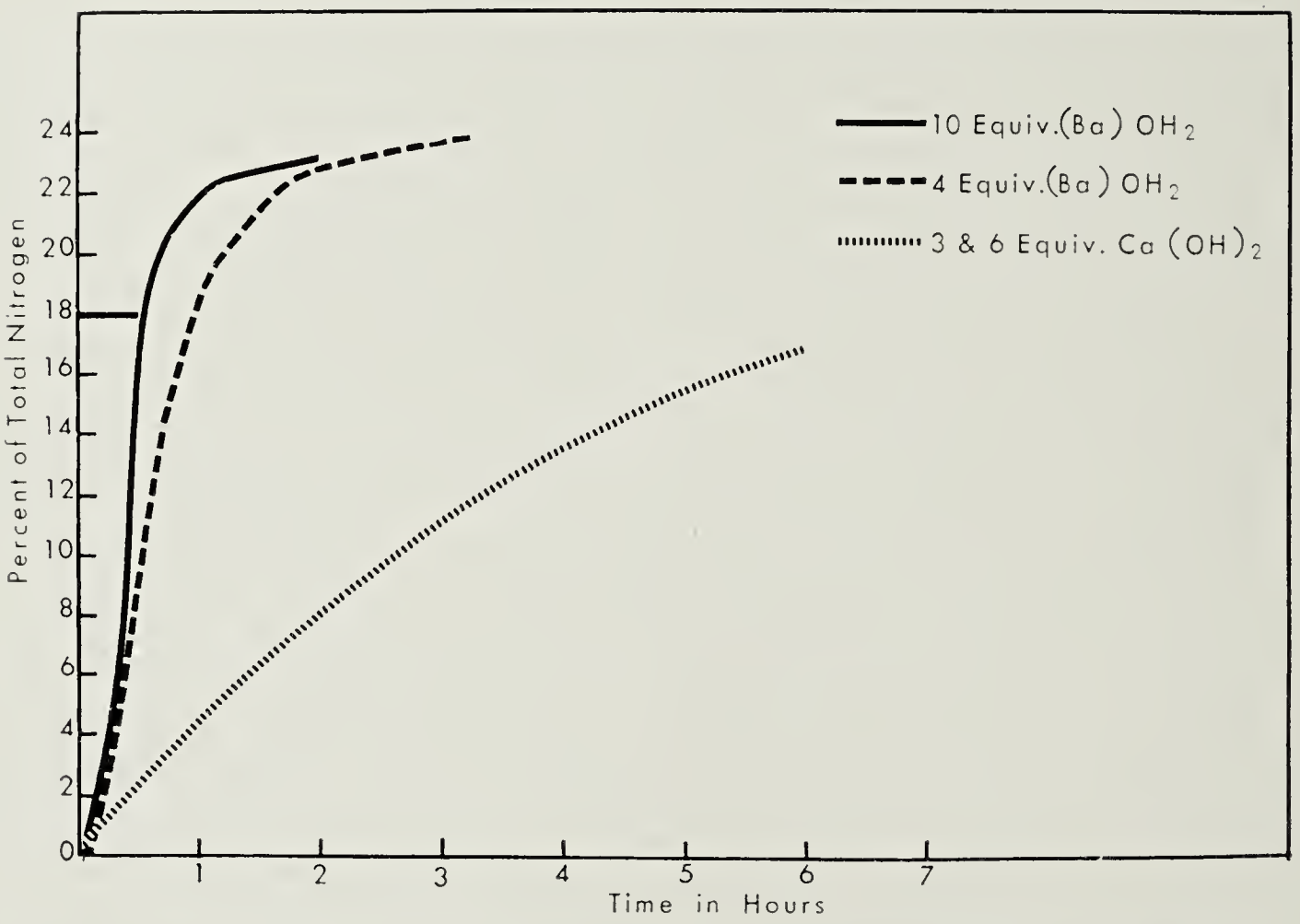
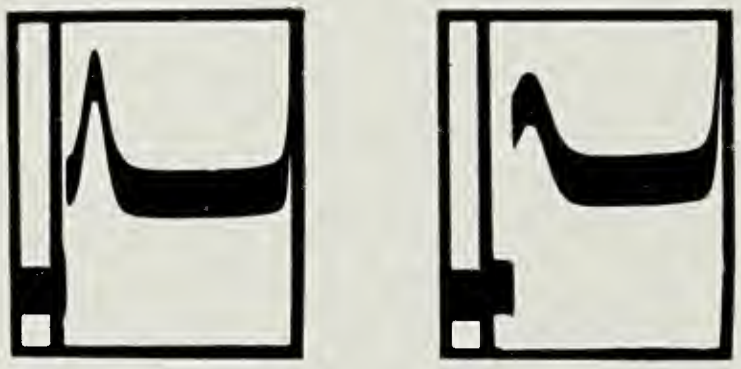


FIG. 2.—Rate of NH_3 liberation from zein by different equivalents of $Ba(OH)_2$ and $Ca(OH)_2$ based on non-peptide amide groups.



A. Zein (S_{20}=1.60)

B. Deamidated Zein (S_{20}=1.20)

FIG. 3.—Ultracentrifuge patterns, 255,000 g., 112 minutes, conc. 1.0% in 76% ethanol and 0.9% sodium acetate.

pers. comm., Feb. 7, 1951). The bland taste of the water-soluble zein indicates usefulness as a carrier or emulsifier in pharmaceutical preparations, as well as in bakery and pastry products.

SUMMARY

By controlled hydrolysis, the non-peptide amide groups of zein can be converted into carboxyl groups. When approximately 40% of these amide groups are hydrolyzed, zein becomes soluble in water at a neutral pH. This deamidated zein can be precipitated by adjusting the pH to 4.0 and recovered from solution.

Aqueous solutions of deamidated zein have whipping and emulsifying properties, indicating usefulness in food and drug products.

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CHEMISTRY

ABSORPTION OF OXYGEN BY BLOOD PLASMA FRACTIONS IN ALKALINE MEDIA

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When a variety of plant and animal proteins is subjected to oxygen in alkaline media, absorption of gas ensues. The uptake of oxygen is due primarily to the cysteine or cystine contents of the proteins and, of the other amino acid residues investigated, only tyrosine, tryptophan and histidine contribute to a very small (each under 10 μl.0_2/mg.) but definite degree (Gershbein, *et al.*, 1953).

The present study was undertaken with the view of ascertaining variations in oxygen uptake among blood plasma fractions isolated by way of the well-known procedure of Cohn and associates.

Experimental

Proteins. — The human plasma fractions were obtained from the Laboratory of Physical Chemistry and Public Health of Harvard University. Armour and Company was the source of porcine, ovine, canine, and equine fractions.

General Procedure. — The Warburg apparatus was employed in the determination of oxygen absorption (Umbreit, *et al.*, 1949). A weighed sample of protein togther with 2 mls. of distilled water was introduced into the main chamber of the flask and 1 ml. of 3.0 N NaOH was placed in the side-arm. The flask was attached to the manometer and the system gassed with pure oxygen prior to insertion into the bath maintained at 37.5° C. When constant conditions obtained, the alkali was tipped into the main chamber and readings were taken over a period of 20 hrs. Stirring was continued without interruption. Generally, up to ten determinations were carried out for each protein fraction.

Results

Oxygen uptake values expressed as microliters of oxygen absorbed by one milligram of the human plasma fractions together with the respective average deviations from the means appear in Table 1. Findings for select hog, sheep, dog and horse fractions are shown in Table 2. The latter also contains oxygen uptake values for porcine and ovine plasma samples employed in the fractionation.

Discussion

Each of the plasma fractions displayed oxygen uptakes in sodium hydroxide (final concentration: 1.0 N), the rate of absorption being greatest during the first two hours of reaction. The respective values are essentially "saturation" figures

TABLE 1.—Oxygen Uptake Values for Human Blood Plasma Protein Fractions Subjected to Treatment with Alkali (Time: 20 Hr.).

Fraction	Prominent components	Average microliters oxygen/mg. ± average deviation from mean
I	fibrinogen	2.48 ± 0.31
II	γ-globulin	3.53 ± 0.57
III	β_1-lipoproteins β_1-lipid-poor euglobulins and isoagglutinins	4.17 ± 0.18
IV + V	albumin, $\beta_1$metal -containing proteins, α_2-glycoproteins, α_2-mucoproteins, α_1-lipoproteins and iodo-proteins	5.53 ± 0.80
V	albumin	6.12 ± 0.81

TABLE 2.—Uptake of Oxygen by Plasma Protein Fractions of Various Species in Aqueous Sodium Hydroxide (Time: 20 Hr.).

Species	Fraction	Average uptake, μl. O_2/mg. ± average deviation from mean
hog	plasma	5.03 ± 0.97
	I	3.50 ± 0.17
	II	4.29 ± 0.35
	IV-1	4.09 ± 0.40
	V	6.84 ± 0.75
sheep	plasma	5.93 ± 0.11
	II	4.88 ± 0.17
	IV	5.36 ± 0.78
dog	I	3.89 ± 0.46
	V	6.21 ± 0.10
horse	I	3.43 ± 0.21
	IV	3.61 ± 0.39
	V	5.71 ± 0.75

under these conditions, and increases in alkali concentration did not markedly alter the present uptakes.

For the human plasma fractions (Table 1), oxygen absorption was lowest with fibrinogen or Fraction I and increased progressively to the albumins (Fraction V) which displayed a maximal uptake value (6.12 ± 0.81 μl./0_2/mg.). These findings are consistent with the amino acid analyses, although the pertinent published data are sparse. Thus, the cystine content of blood albumin ranges two to three times higher than that of fibrinogen or the globulins; the levels of tyrosine, tryptophan and histidine, each of which figures to only a minor extent in the absorption of oxygen by proteins, occur in much narrower limits (Block and Weiss, 1956: 254-255, 341).

Except for minor discrepancies, the trend noted with the human proteins is also reflected in the findings with fractions from the four animal species listed in Table 2. As would be expected, plasma samples as such gave rise to uptake values which were higher than those of the corresponding Cohn fractions except for the albumins (Fraction V). This is exemplified in the last table by the porcine series.

SUMMARY

Protein fractions obtained from human plasma by the Cohn procedure absorb oxygen when exposed to the gas at 37.5° C in 1.0 N NaOH. The uptake values (μl./0_2/mg.) were determined in the Warburg apparatus and found to be least for fibrinogen (Fraction I) and highest for the albumins (Fraction V),

thereby paralleling the respective cystine contents. Similar trends were also noted for several hog, sheep, dog and horse plasma fractions.

Acknowledgment

This study was aided by a grant from The Toni Division of the Gillette Company, Chicago, Illinois.

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THE EFFECT OF ISONIAZID ON THE IMMUNITY PRODUCED BY VACCINATION OF GUINEA PIGS WITH BCG

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Since vaccination against tuberculosis with BCG (Bacillus Calmette-Guerin) is practiced throughout the world and because of the proposal that isoniazid be given prophylactically to susceptible groups of people (Ferebee and Palmer, 1956:1) it is essential that we determine whether or not the immunity established by BCG vaccination is influenced favorably or unfavorably by the administration of this antimicrobial agent.

Adequate evidence has been presented that vaccination of guinea pigs with the attenuated BCG bovine strain of tubercle bacilli confers a partial immunity against virulent tubercle bacilli (Sher and Czaja, 1956:95). Similarly a comparable degree of protection is obtained when guinea pigs are infected with comparatively small amounts of pathogenic tubercle bacilli and are subsequently treated for ten weeks with sulfone derivatives (Sher and Kloeck, 1953:66) and with isoniazid (Sher and Czaja, 1956:95). This immunity exists even though, as is the case with isoniazid therapy, the disease is suppressed so that there is morphologically or histologically no evidence of tuberculosis 32 weeks after the infection (Sher, *et al.*, 1957:298). It was postulated that the drugs retarded the rate of bacterial growth and thus enabled the animal body to develop a moderate degree of resistance against a subsequent endogenous spread or externally administered infection (Sher and Czaja, 1956:95-96). However, it has been reported recently that when mice were infected with minute, yet lethal, amounts of tubercle bacilli and were subsequently treated with isoniazid, no protection was observed (Dubos, *et al.*, 1956:546). The question, therefore, arises whether isoniazid will enhance or deter the immunity imparted by BCG vaccination. The response could be similar to the action obtained against minute amounts of virulent organisms, because of the attenuated character of BCG, or might be as it is with the larger inoculum of virulent tubercle bacilli.

These studies were intended to compare statistically the average survival times of guinea pigs vaccinated with BCG in combination with isoniazid with those of non-vaccinated tuberculous control animals. For additional "controls", comparisons were also made with BCG vaccinated animals receiving no isoniazid and with guinea pigs with latent or arrested tuberculosis produced by treatment of a virulent infection with isoniazid.

Materials and Methods

Fifty-one guinea pigs weighing between 400 and 600 gms. were adjusted to the environment of the animal quarters and were divided into 5 groups. Two of these groups, A and B, were vaccinated with BCG obtained from the Tice Laboratories. On the same day group C was inoculated with H37Rv, a virulent human strain of tubercle bacilli. Groups D and E received no inoculation at this time.

Group A consisted of 5 animals injected subcutaneously in the right inguinal region with 0.1 mg. BCG; 134 days later each animal was injected in the left inguinal region with 0.1 mg. H37Rv. This group served as the "immunized, tuberculous group" and was observed until death.

Group B consisted of 13 animals vaccinated as in group A. Starting 7 days after the vaccination they received daily treatment for 60 days of 20 mgs. isoniazid per animal in one ml. of 10% sucrose solution mixed with lettuce. One hundred and thirty-four days after vaccination the animals were inoculated with H37Rv as in group A and observed until death. This group served as the "immunized, treated, tuberculous group".

Group C consisted of 10 guinea pigs injected subcutaneously in the right inguinal region with 0.1 mg. H37Rv, a virulent human strain of tubercle bacilli. Starting 7 days after the inoculation they received daily treatment of isoniazid as in group B; 134 days after the primary infection they were reinfected with 0.1 mg. H37Rv subcutaneously in the left inguinal region. This group served as the "treated, reinfected group" and was included in these experiments to compare the effectiveness of immunity obtained by means of a virulent strain of tubercle bacilli suppressed by isoniazid treatment with that obtained by BCG vaccination.

Group D consisted of 12 guinea pigs that received no injection until 134 days after groups A and B were vaccinated with BCG and group C received the primary H37Rv infection. These animals were inoculated simultaneously with the virulent H37Rv infection of groups A and B and the reinfection of group C; thus they served as primarily infected controls for the evaluation of resistance against infection. They served as the "tuberculous controls".

Group E consisted of 11 normal guinea pigs which were neither infected nor vaccinated and received no drug. They served as the "healthy controls".

Groups A, D, and E, received sucrose solution mixed with lettuce during the period that groups B and C received isoniazid treatment.

Immunity was expressed in terms of the average survival time of each group, calculated from the day of infection with H37Rv or 134 days after the vaccination with BCG. The observed difference, "OD" (Table 1), obtained by comparing the average survival time of the non-vaccinated "tuberculous controls" of group D with each of the other groups, gave a measure of immunity, or resistance to tuberculous infection. This observed difference, divided by the standard error of this difference, "SE-diff", gives the re-

liability quotient OD/SE diff (Waugh, 1938:157) for each group thus compared. A quotient of 2.0 or higher was acceptable because of the small numbers of animals used, and indicated that the likelihood was 21 to 1 that these results were not due to chance occurrence. Appropriate precautions based on the small numbers used were taken in each instance in estimating the statistical reliability.

The animals were dissected carefully to establish gross evidence of tuberculosis. The post mortem rating was estimated according to the method of Sher and Kloeck (1946: 251).

Results

All of the animals included in Table 1 gained weight constantly during the 134 days between vaccination and the challenging infection, at which time they weighed between 600 and 800 gms. On this basis the animals reacted similarly to the normal groups up to the date of the challenging infection with H37Rv, regardless of whether or not they were previously vaccinated as in groups A and B or infected and treated as in group C. These results are similar, in effect, to those obtained when BCG vaccination did not increase the mortality rate of guinea pigs (Sher and Czaja, 1956: 94), and isoniazid provided complete protection against a virulent infection during a similar period (Sher, *et al.*, 1957:297).

The non-vaccinated "tuberculous controls" of group D (Fig. 1) showed a rapid and almost constant mortality rate during the seven months following the challenging infection with H37Rv, while the mortality rate was considerably lower for the "immunized treated tuberculous" animals of group B. During the first three months the death rate of the former was three times that of the latter, and at seven months when none of the tuberculous controls were alive one-third of the immunized guinea pigs were living.

There was little difference in the mortality rate between group B and each of the other immunized groups, A and C. Each group showed some degree of protection, for at any time during the survival period the percent of survivors was greater than that of the "tuberculous control" group.

Ninety percent of the "healthy control" animals of group E were alive at 12.5 months when all of the animals of the other groups were dead. The mortality rate of group E was very much lower than that of the other groups.

The average survival time calculated from the day of injection with H37Rv was considerably longer for group B than for the "tuberculous control" animals of group D. The observed difference of 66 days portrays a partial resistance against a virulent infection with a reliability quotient OD/ SE diff of 2.1 (Table 1). Although the observed difference of 88 days between groups A and D was somewhat greater, the reliability or statistical significance was somewhat less than that obtained for group B. However, for a similar group (Sher and Czaja, 1956:93) of 18 guinea pigs the average survival time was 206 days as compared to 209 days for group A and the reliability quotient of 2.8

TABLE 1.—Average Survival Time from Time of Infection with H437Rv, 134 Days after BCG Vaccination.

Group	Number of animals	Vaccination or primary infection	Isoniazid therapy	Infection or reinfection 134 days after vaccination	Average survival time	SE	OD	OD/SE diff.
A. Immunized, tuberculous	5	BCG	none	H37Rv	209	62	88	1.6
B. Immunized, treated, tuberculous	13	BCG	60 days	H37Rv	187	26	66	2.1
C. Treated, reinfected	10	H37Rv	60 days	H37Rv	192	32	71	2.1
D. Tuberculous control	12	none	none	H37Rv	121[1]	19	.....	.....
E. Healthy control	11	none	none	none	>502	24	>381	>12.0

[1] Calculated from date of infection.

was highly significant statistically. This comparison permitted greater confidence in the results calculated for group A.

Calculation of the observed difference between the average survival times of the two BCG vaccinated groups, one without and the other with isoniazid treatment (groups A and B), gave a relatively small value of 22 days, which proved to be statistically not significant.

The observed difference of 71 days for the "treated, reinfected group" showed approximately the same degree of immunity as that obtained with BCG vaccination and isoniazid. The quotient of 2.1 was acceptable. This observed difference approximated the value of 75 days obtained from a similar series of 52 animals, and these latter results were highly significant statistically (Sher, *et al.*, 1957:297).

An average survival time of 292 days was calculated for BCG vaccinated animals which received neither isoniazid nor a virulent challenging infection (not tabulated). This result was sufficiently high to require no detailed statistical analysis to establish that a subsequent virulent infection shortened the lives of these vaccinated animals. On the other hand, these BCG vaccinated animals did not live as long as the "healthy controls".

Upon anatomical examination each "tuberculous control" animal showed severe tuberculous changes, except for the one guinea pig that died two weeks after the infection. In this instance the gross, postmortem rating (Sher and Kloeck, 1946:251) was 20%. In another animal the rating was 60%, and for the remainder it was 100%. The post mortem ratings for the immunized groups ranged from 35 to 100%. These latter showed severe tuberculous involvement, but to a lesser degree than that of group D.

Discussion

When guinea pigs are vaccinated with BCG in combination with isoniazid, measurable benefits in the form of immunity or resistance against tuberculosis are obtained. From Figure 1 it is apparent that during the three months immediately following the inoculation with H37Rv, the mortality rate of the vaccinated animals was markedly lower than that of similarly infected, non-vaccinated, control animals. This may be attributed to the slow initial rate of bacillary growth in the immunized animals which produced only minimal or sub-lethal amounts of tuberculosis up to this point.

Some evidence of immunity was present also during the remainder of the survival period even though the mortality rate was increased. It is shown in Figure 1 that the slope of the curve for the immunized group (B) is shallower than for the control group (D) for this period.

The accelerated mortality rate was associated with extensive tuberculous involvement found on postmortem examination of the animals dying during this latter period. The immunity described here in the presence of this extensive involvement corresponded to that found when tuberculous guinea pigs were treated with sulfone derivatives (Sher and Kloeck, 1953:66). In this experi-

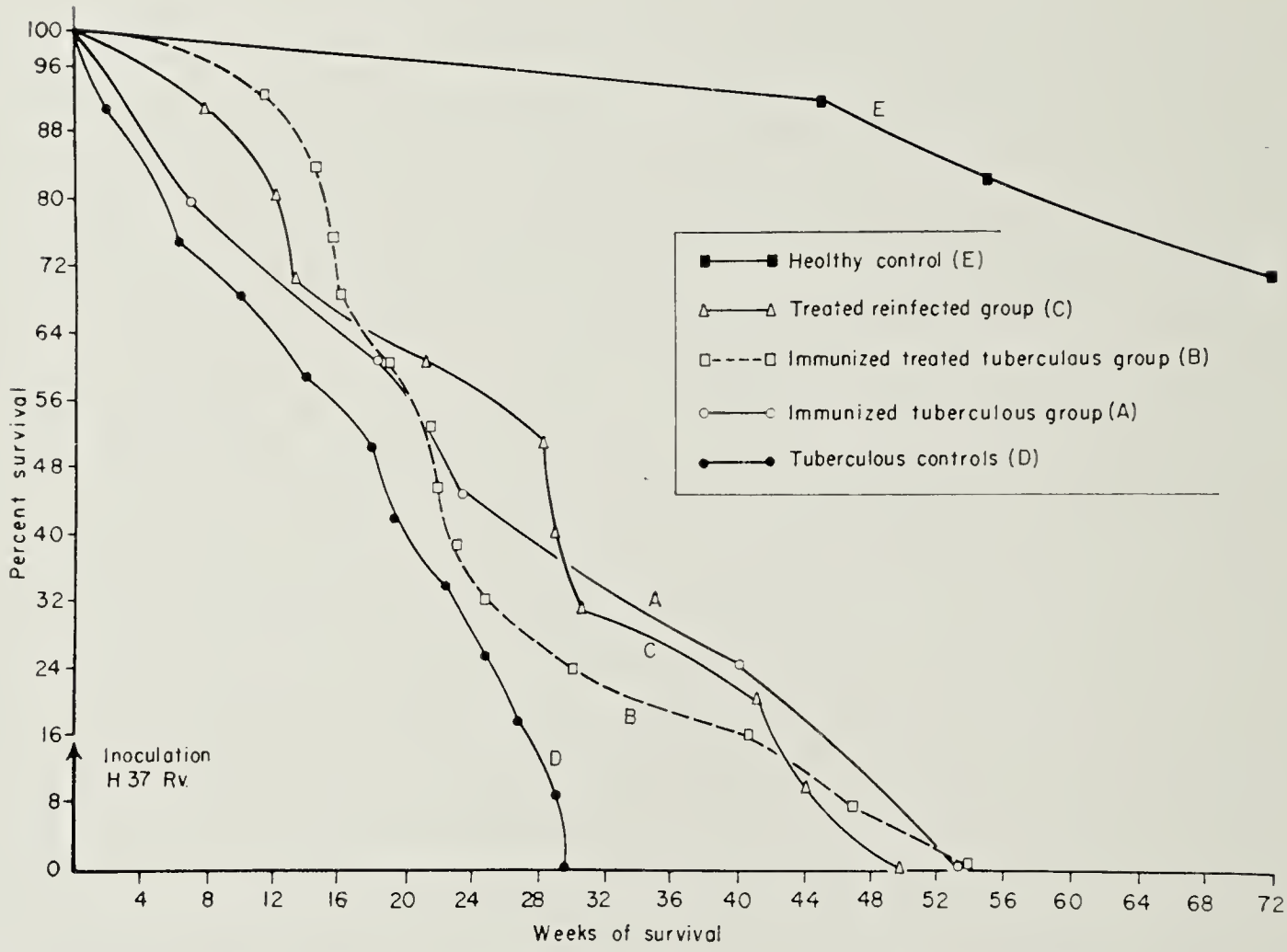

FIG. 1.—Survival of the different groups of guinea pigs. Symbols indicate times of death.

mental study we found that the treated animals lived more than twice as long after treatment ended than the entire life span of the untreated controls, despite the presence of large amounts of tuberculosis.

Examination of the mortality rates and nature of the curves for the vaccinated animals not receiving isoniazid, group A, and for the "treated, reinfected" animals of group C led to practically the same conclusions as were obtained with group B when each of these groups was compared with the tuberculous controls. Also, there was little difference between the immunized groups A, B and C when they were compared with each other.

There is no basis for a detailed discussion of the slight deviations observed in each curve as they appear in Figure 1. However, a summation of these and other factors is inherent in the statistical data of each group tabulated in Table 1.

These data showed that vaccination with BCG produced a moderate degree of immunity, and that this immunity was not significantly influenced by the administration of isoniazid. Although the average survival time was somewhat less with the use of isoniazid, the observed difference between these two groups was too small to be statistically significant.

SUMMARY

Preliminary experiments have shown that the immunity obtained when guinea pigs were vaccinated with BCG was not significantly influenced by the administration of isoniazid.

The immunity obtained when a virulent tuberculous infection was suppressed with isoniazid was approximately equal to that obtained with BCG vaccination.

Acknowledgments

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STUDY OF A BLOOD POLAROGRAPHIC CHANGE ASSOCIATED WITH WALKER TUMOR GROWTH

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A cancer test based on polarographic analysis of blood was proposed and partly developed by Brdicka in 1937. Principally, the method involves precipitation of blood protein by sulfosalicylic acid and polarographic analysis of the filtrate in the presence of ammonium hydroxide and hexamine cobaltic chloride. For details see Brdicka (1947) and Kolthoff and Lingane (1952). The polarographic activity is associated with a mucoprotein, isolated electrophoretically in the alpha globulin fraction at pH 8.4 (Greenstein and Haddow, 1953). Homolka (1954) analyzed the electrophoretic fractions of blood serum applying Brdicka's method and found that alpha and beta globulin-like substances showed highest polarographic activity.

Experimental animal work has been less extensive than clinical diagnostic work. Crossley (1941) demonstrated that the polarographic changes of blood caused by pneumococci infection were similar to those caused by cancerous growth. Further work (Klatt, *et al.*, 1941) showed that the polarographic test might be accurate in advanced Flexner-Jobling carcinomata in rats. Miner, *et al.*, (1941) found that the administration of carcinogenic substances reduced the blood levels of sulfur-containing amino acids in a way analogous to that produced by cancerous growth .Winzler, *et al.*, (1944) showed that pyogenic infections and cancerous conditions effected similar polarographic changes. Such factors as differences in strain, sex, age, and diet, liver cirrhosis or regenerating liver did not have any notable effects. Spontaneous regression or extirpation of tumor was accompanied by a rapid return to normal. Westfall, *et al.*, (1945) found changes in the polarographic blood picture of rabbits with Brown-Pearce carcinoma, while the benign tumor had no effect. No correlation was found between the degree of malignant involvement and the polarographic response. As a result of their study with Walker 256 tumor, Mundro and Boyd (1951) suggested that the relationship between tumor size and animal weight might be a determining factor for inducing polarographic blood changes, although their experimental series was not large enough to make any final conclusions. Neish (1954) studied Walker 256 tumors, applying the Waldschmidt-Leitz test on blood samples, but could not detect any significant correlation between tumor size and polarographic blood response.

On the basis of the available literature it was felt that there were no extensive studies dealing with the progression of the polarographic changes during tumor growth. The available evidence indicated that the

correlation, if any, between the degree of the polarographic response and tumor size does not exist to any significant degree. Therefore, the objective of this study was a careful quantitative study of the changes of the polarographic active substances in blood during tumor growth.

The general plan of the work undertaken can be outlined as follows:

1. The daily levels of the polarographically active substances in blood were determined in non-tumor animals to establish the range of normal values.

2. The polarographic waves of normal and cancerous blood were compared, taking into consideration both quantitative and qualitative changes in the wave pattern. Special emphasis was placed on the changes associated with the early stages of tumor growth and deviations from normal wave pattern occurring in non-tumorous rats.

3. The magnitude of the polarographic changes in blood was correlated with the age and size of the tumor, to ascertain whether or not a relationship existed.

Materials and Methods

Repeated blood analyses were performed on each animal before and after transplantation of tumor. The blood (0.20 ml.) was withdrawn from the caudal vein.

The blood samples were treated as described by Winzler, *et al.*, (1944). Appropriate amounts of fresh stock solutions were mixed each day to make the final reagent used in polarographic analysis.

A Sargent model XXI polarograph was used. The dropping mercury electrode (t = 2.56 sec., drop time; m = 3.76 mg., drop weight) was the cathode. One ml. of mercury in the test tube (14 mm. by 125 mm.) served as a stable anode. The drop distance was kept constant. The voltage span was from +0.20 to —2.0 volts; applied voltage was from 40.0 to 80.0% of the voltage span. The height of the waves was expressed in millimeters, where 10 mm. corresponded to a current of 3.0 milliamperes. The method for determining wave height and half-wave potential has been described by Willard, *et al.*, (1951). The diffusion current of the first wave due to the reduction of cobalt was used as a baseline for the measurement of the second wave due to the blood mucoproteins. The changes in half-wave potential were expressed as the variations in distance in millimeters from the starting point of the polarogram to the point on the abscissa (applied potential) corresponding to the midpoint of the wave height. A shift of 10 mm. in either direction corresponded to ±0.068 V. The height of the catalytic currents was measured at the following points of the applied potential: (a) single waves from —1.35 to —1.55 V; (b) double wave—first wave from —1.15 to —1.25 V and second wave from —1.35 to —1.55 V.

Animals used were Sprague-Dawley rats of both sexes, 180 to 250 gms. in weight before tumor transplantation.

A Walker 256 tumor cell suspension was used for transplantation. It was obtained by gently grinding 1 gm. of tumor tissue in 10 mls. of sterile physiological saline in a mortar and filtering through gauze. The

saline contained 1,000 Units of crystalline potassium penicillin G per 1 ml. Two-tenths milliliter of this suspension was injected subcutaneously into the inguinal region of the rat. Growth of the tumor was followed by repeated measurements of three diameters of the tumor using a vernier caliper. The volume of tumor was expressed according to the formula, $V=0.52\ d^3$, where $d^3=$ products of three diameters (Schrek, 1936). For statistical methods employed see Hill (1952).

Results

Before going into a detailed discussion of the experimental results, a few remarks regarding the method used for polarographic recording may be pertinent. Since the emphasis was placed on changes in half-wave potential in tumor-bearing animals and in normal animals with a tumor-like wave pattern, a polarographic recording covering 40 to 80% of the applied potential was necessary. It was reasoned that any observed differences in both conditions might be of differential diagnostic value. Secondly, this polarographic recording was necessary to obtain a well defined second wave. It seemed that the presence of a well developed second wave might be a more objective criterion of cancerous growth than the establishment of a definite range of normal wave height as opposed to definite ranges of cancerous wave height.

The reagent polarographic wave values were as follows: (a) wave height, 23.9 mm. ±0.3 (mean ±SE); (b) half-wave potential, 89.2 mm. ±1.9 (—1.25 V); (c) number of determinations, 67 (n=67).

Table 1.—Distribution of Single and Double Wave Animals before Transplantation of Tumor.

Animal group	No. animals	% animals tested
Single wave animals[1]	42	79.2
Double wave animals[2]	11	20.8
a. three times	3	5.7
b. two times	3	5.7
c. one time	5	9.4

[1]Single blood wave three times.
[2] Double blood wave at least once in three consecutive tests.

The polarographic values of reagent solutions showed close agreement and good reproducibility. The wave height of the reagent was a few millimeters lower than that of solutions containing blood filtrate from animals giving the single wave (Tables 2, 3).

Table 1 illustrates the incidence of "single wave" animals before tumor transplantation. Approximately 80% of all animals tested manifested single wave pattern in three consecutive tests on different days. The double wave animals constituted approximately 20% and could be divided into three classes, according to the observed frequency of the double wave. Animals exhibiting the double wave two or three times were in approximately the same proportion, while those showing the double wave once in three determinations constituted the largest percentage. Apparently, the double wave in nontumorous animals was not a common phenomenon. In cases where it occurred, it was not consistent in its presence and showed wave height fluctuations in both directions. These

findings with "normal" double wave animals were just the opposite to those observed in animals with well developed tumors. In the latter cases the double wave was a constant phenomenon with a definite tendency to increase with tumor growth (Table 4). The mean values (Table 2) do not very well illustrate this point with reference to the non-tumorous animals, though the data on individual animals point it out more clearly. The magnitude of the second wave in non-tumor animals was in some cases comparable to that caused by tumor growth. No significant difference could be detected in the half-wave potential of tumorous animals and so-called double wave animals without tumors. It can be said that, although there were neither qualitative nor quantitive differences between the double waves of "normal" and tumor animals, in an absolute sense, there were certain characteristics (constancy of appearance, daily variations) which may help to differentiate between these two types of the double wave.

The percentage of the successful tumor transplantations was approximately the same in both single and double wave animals.

The wave height and half-wave potential of normal single wave animals did not show any appreciable variations, (Table 3). This becomes evident when the daily means are compared with the grand mean of all rats tested (42 animals, three determinations in each case)—wave height, 24.4 mm. $\pm$0.3, and half-wave potential, 89.2 mm. $\pm$0.6

The relationship between the double wave and the tumor age is summarized in Table 4. At early stages of tumor growth seven to nine days after transplantation, no significant changes in the magnitude and the incidence of the double wave were observed. Only after ten days was there a significant increase in the incidence of the double wave. With progressive tumor growth, all animals showed the double wave pattern. The height of the second wave exhibited significant increase ten days after transplantation. This

TABLE 2.—Blood Waves of Rats Showing Double Wave before Transplantation of Tumor.

Determination	No. animals		Wave height, mm.[1]		Half-wave potential[1]	
	single	double	single	double[2]	single	double[2]
1st	4 (36.4%)	7 (63.6%)	25.5 $\pm$ 0.8	18.1 $\pm$ 0.8 23.9 $\pm$ 5.5	87.0 $\pm$ 2.8	72.9 $\pm$ 2.0 102.9 $\pm$ 1.7
2nd	4 (36.4%)	7 (63.6%)	29.2 $\pm$ 1.6	18.3 $\pm$ 0.8 28.0 $\pm$ 3.4	88.5 $\pm$ 2.7	71.6 $\pm$ 1.1 103.0 $\pm$ 0.2
3rd	4 (40.0%)	6 (60.0%)	31.0 $\pm$ 1.4	19.5 $\pm$ 1.2 23.7 $\pm$ 7.3	90.8 $\pm$ 3.7	75.5 $\pm$ 2.1 101.5 $\pm$ 3.0

[1] Mean $\pm$ SE.

[2] Height and potential of 1st wave indicated first.

TABLE 3.—Daily Variations of Blood Waves before Transplantation of Tumor.

Determination	No. animals		Wave height, mm.[1]		Half-wave potential[1]	
	single	double	single	double[2]	single	double[2]
1st	31 (88.6%)	4 (11.4%)	25.4±0.1	17.2±1.1 28.5±9.0	87.7±1.1	73.0±2.2 105.5±0.6
2nd	31 (88.6%)	4 (11.4%)	27.8±0.6	17.5±0.3 33.5±4.0	89.7±1.1	72.5±1.2 106.2±1.4
3rd	31 (93.9%)	2 (6.1%)	29.0±0.5	16.5±0.4 17.0±1.4	89.7±1.0	77.0±0.0 102.0±0.0

[1] Mean ± SE.
[2] Height and potential of 1st wave indicated first.

point coincided with the first marked increase in the frequency of its occurrence. The maximum height of the second wave was reached after 17 to 20 days. At this stage of tumor growth the blood analyses were discontinued because the tumor showed a tendency toward necrosis. In cases where necrosis was apparent, the second wave usually exhibited a tendency to increase as necrosis advanced until its height reached a maximum with a decline later.

The statistical analysis of the height of the second wave, after the tumor became well established, showed that the following observed differences were significant: 1) between 10-11 and 15-16 days, $t>3$; 2) between 10-11 and 18-20 days, $t>5$; and 3) between 13-14 and 18-20 days, $t>2$. The observed differences in height between other time intervals (10-11 and 13-14 days, 13-14 and 15-16 days, 15-16 and 18-20 days) proved to be insignificant. This could be partially explained by the variations in rate of growth of individual tumors. In order to examine the relationship between the volume of tumor and the height of the second wave a coefficient of correlation was determined. Animals used for this study had readily measurable tumors and well defined second waves. A positive coefficient of correlation, 0.45 ±0.12, was found with t value of 3.75, which is highly significant (Hill, 1952). These results would suggest that the polarographic test might be of value for following the growth of tumors. In summary, it could be stated that the second wave showed a higher frequency of incidence and a definite tendency to increase both with the age and the size of the tumor.

A closer examination of the relationship between the height of the second wave and the corresponding half-wave potential revealed that there was some positive correlation between these two variables. The average figures (Table 4) do not show this correlation in a clear fash-

TABLE 4.—Blood Waves after Transplantation of Tumor.

Days after transplant	No. animals		Wave height, mm.[1]		Half-wave potential[1]	
	single	double	single	double[2]	single	double[2]
1-2	19 (90.5%)	2 (9.5%)	27.5±1.0	17.5±0.4 15.5±3.2	86.8±1.0	75.0±2.1 99.0±0.4
4-6	16 (94.1%)	1 (5.9%)	26.8±1.6	13.0±0.0 12.0±0.0	86.8±0.5	78.0±0.0 104.0±0.0
7-8	19 (95.0%)	2 (5.0%)	28.2±2.6	18.0±0.4 12.0±0.0	89.1±0.7	83.5±3.9 104.0±5.0
10-11	10 (47.6%)	11 (52.4%)	27.8±1.2	16.9±0.5 23.3±4.2	85.7±0.6	78.0±1.4 107.4±1.3
13-14	3 (13.6%)	19 (86.4%)	30.0±3.2	16.3±0.4 35.0±4.5	86.6±1.5	75.0±0.8 109.4±1.5
15-16	0	22 (100%)	.....	17.2±0.5 47.2±4.4	.....	73.3±0.9 110.0±1.5
18-20	0	14 (100%)	.....	17.3±0.9 52.0±5.3	.....	71.0±0.8 106.4±1.6

[1] Mean ± SE.

[2] Height and potential of 1st wave indicated first.

ion, but the values of individual animals (Table 5) illustrate it quite clearly. The negative shift of the half-wave potential is most probably explained by an increased concentration of the metal complexing agent, the sulfhydryl groups of the mucoprotein (Müller, 1951).

DISCUSSION

Objection to the use of the polarographic test has been made because of its unspecificity. Our findings support this objection. It was demonstrated in several "normal" rats with double wave pattern that the double wave disappeared after tumor transplantation and reappeared only when the tumor showed a definite size. Secondly, it was found that the half-wave potentials of the second wave in the blood of tumorous rats and so-called "normal" rats did not exhibit any notable differences. These findings would suggest that in both cases the polarographically active substances were similar. In addition, there exists some electrophoretic evidence indicating that the globulin-like substances in blood are increased both in pyogenic and neoplastic conditions (Bary, 1950; Eldredge and Luck, 1952; Greenstein and Haddow, 1953; Höhne and Künkel, 1954). More direct evidence was provided by Homolka (1954), who polarographically analyzed various electrophoretic fractions of blood serums and found that alpha and beta globulin

TABLE 5.—The Height of the Second Blood Wave and Half-wave Potentials.

Wave height (mm.)	Half-wave potential
25[1]	109[2]
58	11 ,
30	11[1]
53	116
17	112
58	121
12	107
46	116
39	109
70	126

[1] Each pair of values is from same animal.
[2] Expressed in mm. from starting point of polarogram.

fractions containing mucoprotein were most active polarographically.

The question may arise as to what can be undertaken to increase the practical value of this cancer test. In cases of infectious conditions, intensive anti-biotic therapy may be of value in eliminating the complicating effects of infection. There is some clinical evidence showing that by excluding infections this test may be made more sensitive (Robinson, 1948). Secondly, repeated determinations may be of value to eliminate false positive diagnosis, since a normal person will usually exhibit a normal polarographic picture provided no change in his health occurs. The "normal" non-cancerous human cases with abnormal polarographic values tended to show larger variations than those with a normal polarographic picture (Forssberg and Nordlander 1950). Somewhat analogous results were obtained with our non-tumorous rats with double waves which did not appear constantly during repeated determinations and showed a tendency to fluctuate in their heights daily. This is just the opposite to the findings in tumorous rats.

The results obtained in following the polarographic blood changes during the process of tumor growth indicated that there is a definite correlation between these two variables. Such a correlation would suggest that the polarographic test could be a valuable tool in following the course of malignant growth under therapy. There is some clinical evidence that the changes in the condition of prostate cancer are well reflected in the polarographic blood picture (Robinson, 1948).

The value of the method applied in this study to detect the latent precancerous stages of the neoplastic growth does not seem to be high, as indicated by our findings on Walker 256 tumor. Only definitely palpable tumors gave positive diagnosis.

SUMMARY

Repeated polarographic analyses of whole blood, applying the Brdicka test as modified by Winzler, *et al.*, (1944), showed a double wave polarogram at least once in 20% of all non-tumorous rats.

The second wave in non-tumorous rats was a relatively unconstant phenomenon and showed irregular tendency to fluctuate in its size in individual animals. These characteristics of the second wave in non-tumorous rats were just the opposite to those observed in animals with well developed tumors.

The blood double wave due to the tumor growth appeared only when

the tumors showed definite size and progressive growth. This method was not sensitive enough to detect the early (latent) stages before the tumors were well palpable.

Some degree of correlation between age of the tumors and concomitant changes in the height of the second wave was established.

The correlation between volume of the tumors and height of the second blood wave proved to be significant.

The unspecificity of the test was discussed and some suggestions (antibiotic therapy, repeated blood analyses) were offered which might increase the clinical value of this test.

Acknowledgment

J. A. Gylys gratefully acknowledges the support afforded to him by the Cabell Scholarship in 1955-1956.

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STEARIC HINDRANCE EFFECTS OF THE TERTIARY BUTYL RADICAL IN SOME MANNICH CONDENSATIONS

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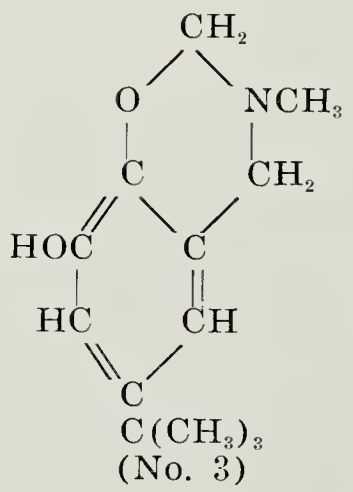
Introduction

Burke (1949:609) prepared 3,4-dihydro-3-cyclohexyl-6-tertiary-butyl-1,3,2H-benzoxazine in good yield by the interaction of cyclohexylamine, formaldehyde, and para-tertiary-butyl phenol in a 1:2:1 molar basis, respectively. Burke, Smith, and Weatherbee (1952:602) reported that a benzoxazine was not formed when 2,4-di-tertiary-butyl-5-methyl-phenol, formaldehyde, and methylamine were interacted in a 1:2:1 molar basis, but instead a good yield of N,N-bis(3,5-di-tertiary-butyl-2-hydroxy-6-methyl-benzyl)-methyl amine was obtained. The presence of the tertiary butyl group in the ortho position to the phenolic group served as a stearic hindrance and prevented the phenolic hydrogen from entering the reaction.

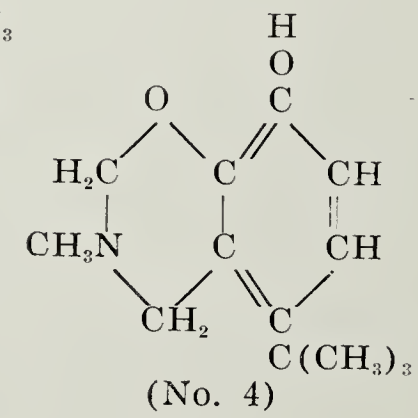
Burke and Weatherbee (1950:4691) found that hydroquinone, formaldehyde, and cyclohexylamine condensed in a 1:4:2 molar basis to give 2,3,4,7,8,9-hexahydro-3,8-dicyclohexylbenzo[1,2-e,4,5-e′] bis-m-oxazine. In unpublished work they found that 2,5-di-tertiary-butyl-hydroquinone failed to undergo a condensation with formaldehyde and primary amines; this indicated that both the phenolic hydrogens and the ortho nuclear hydrogens were inactivated.

Discussion

In this investigation Mannich-type condensations involving para-tertiary-butyl-catechol (No. 1) and tertiary-butyl-hydroquinone (No. 2) were studied. The former condensed with formaldehyde and methyl amine in a 1:2:1 molar ratio to give 3,4-dihydro-3-methyl-6-tertiary-butyl-8-hydroxy-benzoxazine (No. 3). The structure No. 3 is preferred over the possible isomer 3,4-dihydro-3-methyl-5-tertiary-butyl-8-hydroxy-benzoxazine (No. 4) in view of the fact that 2,5-di-tertiary-butyl-hydroquinone failed to undergo a Mannich condensation to give a bis-benzoxazine.



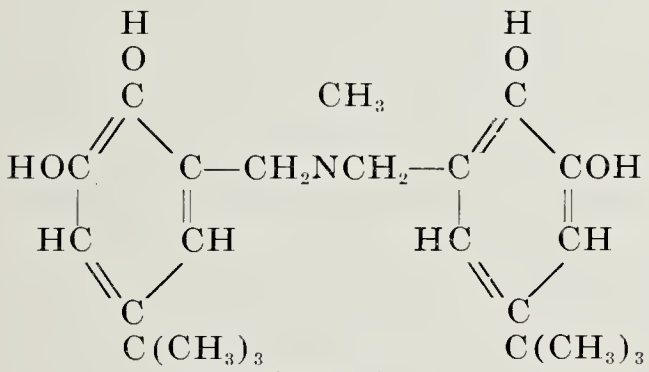
(No. 3)



(No. 4)

Reaction of No. 1 with formaldehyde and methylamine in a 1:4:2 molar ratio did not yield a bis-benzoxazine as did the reaction of catechol, formaldehyde, and methylamine in work reported by Burke and Weatherbee (1950:469).

Condensation of No. 1 with formaldehyde and methylamine in a 2:2:1 molar ratio led to formation N,N-bis(2,3-dihydroxy-5-tertiary-butyl-benzyl)-methyl amine (No. 5). Structure No. 5 was preferred over the possible isomer N,N-bis(2,3-dihydroxy-6-tertiary-butyl-benzyl)-methylamine (No. 6).



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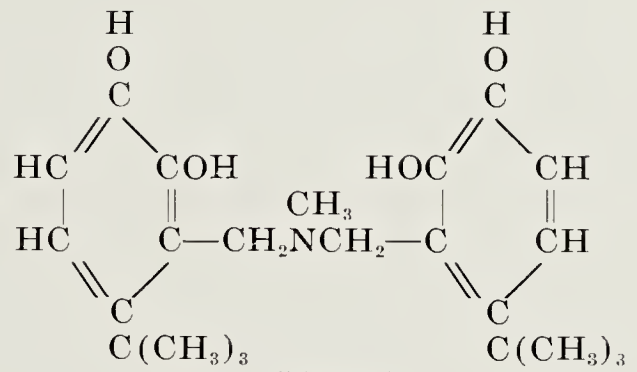

(No. 6)

Thus, the tertiary-butyl group which is meta to one of the phenolic groups in No. 1 prevented the phenolic hydrogen from entering into the Mannich condensations; if structure No. 5 is correct the nuclear hydrogen in the 3-position is inactivated.

Tertiary-butyl-hydroquinone (No. 2) reacted readily with cyclohexylamine and formaldehyde to give a mono-benzoxazine, 3,4-dihydro-3-cyclohexyl-6-hydroxy-7-tertiary-butyl-1,3,2H-benzoxazine (No. 7). The latter structure is assigned instead of the isomer 3,4-dihydro-3-cyclohexyl-5-tertiary-butyl-6-hydroxy-1,3,2H-benzoxazine since all attempts to obtain a bis-oxazine have been unsuccessful. When No. 7 was allowed to react with formaldehyde and cyclohexylamine in a 1:2:1 ratio, with a view of obtaining a bis-benzoxazine, an 83% recovery of No. 7 was secured.

Compound No. 2, unlike compound No. 1, did not yield a bis-benzyl-alkylamine similar to No. 5 and No. 6; all condensations of No. 2 with formaldehyde and primary amines carried out to date on a 2:2:1 molar basis yielded mono-benzoxazines.

Compound No. 1 reacted readily with other primary amines and formaldehyde. The following amines have yielded derivatives of No. 3: cyclohexylamine, benzylamine, alpha-methylbenzylamine, and tertiary-butylamine. Condensations involving No. 2 gave crystalline products also but they were more difficult to purify.

The type of formaldehyde best suited for these reactions was investigated. Commercially available 37% aqueous solution, paraformaldehyde dissolved in methanol containing a trace of potassium hydroxide, and formaldehyde dissolved in 1-propanol were used. The latter source in most cases in this investigation gave a purer initial crude product.

Experimental

The experimental procedures followed in this investigation are illustrated by the following examples:

3,4-dihydro-3-methyl-6-tertiary-butyl-8-hydroxy-benzoxazine (No. 3).—To 30.6 mls. 40% formaldehyde (0.4 mole) in 1-propanol dissolved in 50 ml. of methanol at 10-15° C.

was added 24.8 gms. 25% methylamine (0.2 mole) dissolved in 50 ml. methanol, with shaking over a period of 3 to 4 minutes. To the resulting solution was added 33.2 gms. of para-tertiary-butyl-catechol (0.2 mole) dissolved in 40 mls. methanol. The solution was shaken for several minutes and then placed in a stoppered flask in the dark at 26-28° C. for 28 hours. The brownish solution was decanted to a beaker and placed under a hood to evaporate the solvents, leaving a crude, brownish solid. One recrystallization from methanol gave 33.55 gms. of product (78% yield), melting point 118-122°. After six recrystallizations from methanol the melting point was raised to 130-131°. (Analysis: $C_{13}H_{19}NO_2$: Calculated: C 70.56, H 8.65. Found: C 70.24, H 8.89).

3,4-dihydro-3-cyclohexyl-6-tertiary-butyl-8-hydroxy-benzoxazine. —Yield 59%; m.p. 87-88.5° C. (Analysis: $C_{18}H_{27}NO_2$: Calculated: C 74.70, H 9.41, N 484. Found: C 74.52, H 9.48, N 4.65).

N,N-bis(2,3-dihydroxy-5-tertiary-butyl-benzyl)-methylamine (No. 5). —Condensation was similar to the preparation of No. 3, excepting that 0.2 mole formaldehyde, 0.1 mole of methylamine, and 0.2 mole of para-tertiary-butyl-catechol, were employed to give a 65% yield of No. 5, m.p. 149-150° C. (Analysis: $C_{23}H_{33}NO_4$: Calculated: C 71.28. H 8.58, N 3.62. Found: C 71.28, H 8.67, N 3.80).

3,4-dihydro-3-cyclohexyl-6-hydroxy-7-tertiary-butyl-1,3,2H-benzoxazine (No. 7).—Repetition of the reaction above for the preparation of No. 3, excepting that tertiary-butyl-hydroquinone was used in lieu of tertiary-butyl-catechol, gave a 59% yield of No. 7, m.p. 183-184° C. (Analysis: $C_{18}H_{27}NO_2$: Calculated: C 74.70, H 9.41, N 4.84. Found: C 74.95, H 9.45, N 4.60).

Reaction of No. 7 with Formaldehyde and Cyclohexylamine. — To 1.29 mls. 40% formaldehyde (0.0169 moles) in 1-propanol dissolved in 10 ml. methanol was added dropwise from a pipette 0.97 ml. cyclohexylamine (0.0084 mole) at 15° C. Then 2.45 gms. of No. 7 (0.0084 mole) were added and the mixture was stirred with a mag-mix stirrer for 4 hours. The resulting solution was placed in a stoppered flask and set-aside for 24 hours. Upon evaporation of the solvents and washing the crude solid residue with ethyl acetate, 2.02 gms. of No. 7 (83% recovery) was obtained, m.p. 182-184° C. A mixed melting point with No. 7 gave no depression.

Summary

It has been shown that tertiary-butyl group ortho to a phenolic hydroxyl prevents the phenolic hydrogen from entering into Mannich condensations. When the tertiary-butyl group is meta to a phenolic hydrogen, the nuclear hydrogen ortho to both the tertiary-butyl group and to the phenolic hydroxyl is inactivated. Although both hydroquinone and catechol give bis-meta-benzoxazines upon reaction with primary amines and formaldehyde, neither para-tertiary-butyl catechol or tertiary-butyl hydroquinone yield bis-meta-benzoxazines; only mono-meta-benzoxazines can be isolated.

Acknowledgments

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EFFECTS OF FEEDING BABY PIGS A DIET DEFICIENT IN SODIUM

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INTRODUCTION

A number of studies have been made of animals in a condition of acute or chronic sodium deficiency. In general, a sodium deficiency can be produced by feeding a low sodium diet, by acidosis, by extrarenal dialysis, or by induced diuresis.

A diet containing 7 mgs. sodium per 100 gms. of ration was fed to rats and caused a diminution of appetite which subsequently led to a decrease of fat and protein synthesis (Kahlenberg, *et al.*, 1937). A diet containing 2 mgs. sodium per 100 gms. ration fed to rats caused a loss of weight within a few weeks (Orent-Keiles, *et al.*, 1937). During the eighth to tenth week of feeding the low sodium ration many animals developed a thickening and bluish grey appearance of the corneae. Histological examinations showed the beginning of capsular cataracts. The female rats fed the low sodium ration became sexually mature later than control rats; vaginal smears indicated large, flaky cornified cells characterizing a period of estrus and ovulation which occurred about the same time as the initial changes in the eyes. Both male and female rats fed the low sodium ration had impaired reproductive function, and there was 100% mortality from the 18th to 21st week after the initiation of sodium deprivation. Rats fed a low sodium diet decreased their urinary 17-ketosteroid excretion after the third week of deprivation (Danford and Danford, 1951). Rats fed a sodium deficient ration developed enlarged adrenals with a decreased ascorbic acid content between 30 to 150 days (Danford and Herrin, 1951). Three ten-week-old female puppies fed a ration containing 11 mgs. sodium per 100 gms. of ration exhibited a slight decrease of blood sodium and a slight increase in blood potassium (Turpeinen, 1939). The dogs lost weight continuously. They lived 50, 51, and 66 days when fed this ration.

The sodium requirement of growing swine whose initial body weights were approximately 32 lbs. was studied (Meyer, *et al.*, 1950). The low sodium ration contained 5 mgs. sodium per 100 gms. and was fed to the pigs for six weeks. During this time they gained an average of three lbs. per week. There were no significant differences in plasma sodium levels between control and sodium deficient pigs.

This laboratory has reported the effects of diarrhea on sodium retention by pigs (Reber and Whitehair, 1955; Reber and Yusken, 1956). These findings stimulated an investigation of the effects of feeding to pigs a ration containing a low level of sodium. This is a report of that investigation.

Material and Methods

Five healthy Hampshire pigs, 11 days of age, were placed in individual metabolism cages. Littermate pigs 3 and 4 were maintained on approximately 250 mgs. sodium per 100 gms. of ration until 41 days of age. Pigs 9, 10, and 12 were littermates from another sow. Pigs 9 and 10 were fed 250 mgs. sodium per 100 gms. ration while pig 12 was fed 700 mgs. sodium per 100 gms, ration until 41 days of age.

Salts were supplied as the USP XIV formula with added sodium chloride to supply varying amounts of sodium. The rations were fed as a "milk" containing 20% total solids.

When the five pigs were 41 days of age they were fed a ration containing only trace amounts of sodium. The composition of the ration is given in Table 1 and that of the salt mixture in Table 2. The ration contained 9.4 mgs. of sodium per 100 gms.

Collections of feces, urine, unconsumed feed, and vomitus were made twice each week. The urine was collected in bottles containing sulfuric acid. Samples were kept corked until used for sodium analyses. Feces, unconsumed feed, and vomitus were kept frozen at —10° C. All samples were wet-ashed with sulfuric and nitric acids.

Whole blood samples were taken by heart puncture with heparin used as an anticoagulant. One milliliter of whole blood was diluted with distilled water and frozen. These samples were later thawed and transferred quantitatively to volumetric flasks through filter paper to remove any clots. Sodium and potassium analyses were made by flame photometry using lithium as an internal standard.

Table 1.—Percentage Composition of Low Sodium Ration.

Lard	40.0
Casein	35.0
Lactose	10.0
Dextrose	8.4
Salt mix[1]	5.0
Wheat germ oil (2 I.U.E/gm.)	1.0
Vitamin A and D oil (1000 U.S.P.A., 100 U.S.P.D/gm.)	0.5
Vitamin mix[2]	0.1

[1] See Table 2 for composition.
[2] To 200 gms. of dry ration the following amounts (mg.) of vitamins were added: thiamine, 1.1; riboflavin, 1.8; nicotinic acid, 10.1; inositol, 26.8; choline chloride, 260; p-aminobenzoic acid, 5.0; folic acid, 0.13; biotin, 0.025; pyridoxin, 2.0; calcium pantothenate, 7.1; ascorbic acid, 130.0; vitamin B-12, 0.01; menadione, 0.29.

Hemoglobin was determined by a modification of the cyanomethemoglobin method (Crosby, 1954). Blood non-protein nitrogen and blood urea nitrogen were determined by the method described in the Beckman manual (Chaney and Lamar, 1955).

Results and Discussion

Pig 3 died after it had been fed the low sodium ration for 40 days. The body weight of this pig was maintained until the last collection interval during which it lost 435 gms. Pig 4 was necropsied after being fed the low sodium ration for 32 days. It gained 1775 gms. during the first 28 days of sodium deficient ration. During the two days before it became comatose it lost 900 gms. Pig 9 lost 330 gms. over a 27-day period on the low sodium ration. There was a progressive increase in body weight up to the 14th

TABLE 2.—Sodium-Free Salt Mixture.

Constituents	Percent
Calcium carbonate	37.5
Potassium dihydrogen phosphate	28.4
Potassium chloride	18.9
Ferric citrate	9.5
Magnesium oxide	3.8
Copper sulfate	1.9
	100.0

day and a decline thereafter. There was a loss of 518 gms. during the 72-hr. period preceding death. Pig 10 showed little tendency to gain weight during the first 35 days. There was a loss of 670 gms. from the 35th to the 39th day and little change in body weight up to the end of the experiment. There was virtually no change in body weight of pig 12 up to the 21st day. Pigs 10 and 12 were killed after being fed the low sodium ration for 67 days. This period of time was deemed adequate to show physiological changes.

The average daily gain in weight, sodium intake and excretion, and sodium balance for each pig maintained on 9.4 mgs. sodium per 100 gms. of ration are presented in Table 3. This table also contains data obtained from baby pigs fed the rather high level of 920 mgs. of sodium per 100 gms. of ration (Reber and Yusken, 1956). Only pig 4 gained weight during the low sodium feeding. The feed and sodium intake values were very low. Pig 9 had a negative sodium intake which was presumed to be due to salivation, or possibly to some fecal or urinary contamination that was introduced into the feed bowl. The average daily urinary losses of sodium by these pigs was about 17 mgs. per day. Their fecal loss was small and constant, and there was a rather constant negative balance of about 20 mgs. sodium per day.

In Table 4 is a summary of the very large negative sodium balances exhibited by these pigs during sodium deficiency. These large negative sodium balances occurred as early as the 7th to 11th day and as late as the 46th to 49th day of feeding the sodium deficient ration. In eight of ten balances the large daily negative sodium balance was accompanied by a loss of body weight. The fecal sodium level was not increased during these collection periods, and the large negative balances were a function of sodium losses in the urine. There was some tendency for the sodium to be concentrated in the urine. Urine volumes did not increase appreciably. There was no constant value of sodium loss per given value of body weight loss. The sodium losses varied from 22 to 227 mgs. per 100 gms. of body weight lost. It is tempting to postulate that some of these pigs may have lost sodium from some area of the body in which sodium was sequestered. There were two cases, *i.e.*, pig 4 during the 7th to 11th day of sodium deficiency and pig 10 during the 39th to 42nd day, in which there were no weight losses although there were marked negative sodium balances. These two cases strongly suggest a reserve area for sodium in the body.

Bergstrom and Wallace (1954), by using intraperitoneal dialysis against ammonium chloride in rats, found a decrease in the bone sodium

TABLE 3.—Average Daily Changes that Occurred When Pigs Were Fed Rations Adequate or Deficient in Sodium.

	Sodium per 100 gms. of ration					
	920 mgs.[1]	9.4 mgs.				
		Pig 3	4	9	10	12
Wt. changes, gm..	100 (12)[2]	—36 (7)	50 (5)	—36 (6)	—20 (14)	—25 (14)
Na intake, mg....	768 (12)	3.9(8)	8.5(8)	—0.3(7)	1.4(16)	0.5(15)
Urinary Na, mg...	536 (12)	18.4(9)	18.1(9)	13.9(8)	14.8(17)	19.5(16)
Fecal Na, mg.....	7.7(12)	1.5(9)	3.3(7)	3.6(7)	4.9(16)	3.0(16)
Na balance, mg...	215 (12)	—14.8(7)	—10.6(4)	—24.9(6)	—22.5(14)	—27.8(14)

[1] Reber and Yusken, 1956.
[2] Numbers in parentheses represent the number of three- or four-day trials.

and potassium. Their experiment implicated bone as a reservoir for sodium and potassium. Edelman, *et al.*, (1954) found that 45% of the bone sodium was exchanged with radioactive isotopic sodium within four hours in both man and dog, which indicated a great lability of bone sodium.

Whole blood sodium and potassium, hemoglobin, blood urea nitrogen, and blood non-protein nitrogen were determined on the five pigs used in this experiment, both while they were fed an adequate sodium ration and a deficient sodium ration (Table 5). The average sodium levels of whole blood did not decrease during sodium deprivation, while whole blood potassium did. However, sodium deficiency caused an elevated blood urea nitrogen and blood non-protein nitrogen. Pig 3 had an abnormally high blood non-protein nitrogen during the last collection interval which was probably a reflection of the changes preceding death. Pig 12 consistently had an

TABLE 4.—Summary of Large Daily Negative Sodium Balances.

Pig	Days of sodium deficiency	Weight change, gms.	Urinary sodium, mgs.	Urine volume, mls.	Sodium balance, mgs.
3	7-11	—16	34.5	180	—37.0
3	35-39	—109	53.7	158	—215.0
4	7-11	0	15.4	190	—28.3
9	14-18	—99	43.8	196	—54.5
9	25-27	—173	12.0	150	—37.0
10	35-39	—168	61.0	223	—66.7
10	39-42	+57	96.3	250	—95.7
10	46-49	—37	70.0	90	—79.0
12	25-28	—93	87.7	133	—98.3
12	46-49	—75	34.7	68	—37.3

TABLE 5.—Blood Changes in Baby Pigs Fed a Diet Adequate or Deficient in Sodium.

	Adequate sodium diet	Deficient sodium diet
Hemoglobin, gm. %	10.9 (12)[1]	11.9 (25)
Blood urea nitrogen, mg.%	20.9 (11)	30.0 (29)
Non-protein nitrogen, mg.%	20-45[2]	56.4 (23)
Whole blood sodium, MEQ./1.	94 (26)	93 (32)
Whole blood potassium, MEQ./1.	47 (26)	41 (32)

[1] Numbers in parentheses are number of trials.
[2] See Dukes (1953).

elevated blood urea nitrogen and non-protein nitrogen which was highest on the 25th day of sodium restriction. The blood urea nitrogen rose to 89 mg.% and blood non-protein nitrogen rose to 100 mg.%. This may have reflected some transitory kidney impairment, because the blood levels returned to normal values by the end of the experiment at which time no gross kidney pathology was observed.

The post-mortem examination of the three pigs that died in this experiment did not reveal any specific pathology. Pig 3 was found to have an enteritis with free blood in the lumen. There appeared to be a fatty infiltration of the liver and some degenerative changes of the nephron. Pig 4 had a gastritis, a pulpy kidney, and other characteristics depicting a uremic state. This uremia was verified by the abnormally large blood non-protein nitrogen. Pig 9 was found to have excessive and bloody pericardial fluid along with a flaccid myocardium of the left side, probably due to heart puncture. There also was an enteritis and lymph node congestion. Pigs 10 and 12 were sacrificed after 67 days on the sodium-deficient ration and they had no gross pathological conditions.

SUMMARY

Five apparently healthy Hampshire pigs were fed a synthetic ration which contained 9.4 mgs. of sodium per 100 gms. of ration, from 7 to 15 weeks of age. Sodium balances and blood chemistries were obtained to assess the effects of sodium deprivation. The pigs did not thrive, ate poorly, drank little water and either showed poor gains in body weight or losses. The tendency for high blood urea nitrogen or non-protein nitrogen seen in these pigs indicated endogenous protein breakdown with an inability to remove these nitrogenous wastes. Negative sodium balances persisted during sodium restriction with intermittently large negative sodium balances and urinary sodium losses usually accompanied by large losses of body weight. Although large amounts of sodium were lost in the urine, the level of blood sodium did not change from standard values, and blood potassium concentration decreased. Some large negative sodium balances were neither accompanied by losses of body weight nor changes in blood sodium, which was postulated to indicate a loss from some reserve area in the body such as bone. It was also concluded that the level of blood sodium *per sc* does not appear to be adequate to assess sodium nutrition.

Acknowledgments

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GEOGRAPHY

SAVING WATER IN RESERVOIRS

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Illinois State Water Survey, Urbana

Introduction

From early 1950 through 1955 many central and southern Illinois communities experienced shortages in their water supplies due to a severe drought. By early 1954 there were 41 communities in the southern half of the state that faced serious water supply problems (Hudson and Roberts, 1955). Most of these towns depended upon impounding reservoirs, and runoff had decreased from the normal ten inches per year to approximately one per cent of normal.

Annual water losses due to evaporation are approximately 40 inches in the southern half of Illinois (Roberts, 1953). As water levels in reservoirs dropped, evaporation rose to values greater than municipal withdrawal. In one community which daily pumped one-third of a million gallons from the 65-acre municipal reservoir, local restrictions reduced this to 170,000 gallons per day during July, 1954. However, during that same month, evaporation accounted for 460,000 gallons per day or 2.7 times more than the city demand. Obviously evaporation is a big factor in municipal reservoir accounting, and any means for reducing this loss is worthy of attention.

Research in Evaporation Control

While Illinois was experiencing its drought, a more severe one was affecting the southwestern part of the United States and other parts of the world. In 1952 the Australian Commonwealth Scientific and Industrial Organization began testing an insoluble film to suppress evaporation from small water surfaces. W. W. Mansfield, for whom the Australian process has been named, is the first man credited with developing the idea of using hexadecanol, which comes from whale oil, for reducing evaporation losses from small ponds. In parts of Australia annual evaporation amounts to 10 feet. Mansfield found that on ponds up to two acres in area a coating of hexadecanol could reduce evaporation by at least 25%, and as much as 45%.

For more than 40 years physical chemists in the United States have been carrying on experiments with monomolecular layers. Their studies provide basic data for present evaporation suppression projects.

The drought in Texas caused the Southwest Research Institute to start a program early in 1956 to investigate means of retarding water evaporation. The United States Bureau of Reclamation and the United

FIG. 1.—Evaporimeters at Urbana, Illinois, evaporation station.

States Geological Survey have both made fundamental studies on energy balance and film spreading techniques and several laboratory studies of evaporation savings. A team of North Texas State College students in collaboration with six government agencies has conducted studies on physical and biological effects of hexadecanol in a five-acre lake near Oklahoma City. The Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, has made studies on the toxicity and biological oxidation of monomolecular films used in reservoir evaporation control.

The Illinois program.—The work of the Illinois State Water Survey in this field has been concentrated on the measurement of differences in evaporation rates from pairs of identical water containers where one surface is unprotected and the second surface has a coating of hexadecanol. These studies have also been applied to a 100,000-gallon capacity tank.

The Survey operates three evaporation stations in northern, central, and southern Illinois. These are Class A pan installations and Stevens-Roberts evaporimeters (Roberts, 1954) which record water losses graphically from a three-square foot surface. In February, 1956, two identical evaporimeters (Fig. 1) were installed at the Survey's Urbana evaporation station. One milligram of hexadecanol was applied to one surface; the second had water without any protective coating. The water containers were approximately two feet in diameter and one-inch deep, with built-in overflows to waste excess precipitation. During the spring and early summer months the effect of the monolayer cover was negligible, but there were individual days during July and August when the pan with the hexadecanol cover had water loss of nearly 30% less than the pan without the chemical cover. Figure 2 shows the cumulative evaporation from both pans for a three-month period. The average reduction in evaporation was 10% for the period.

In June, 1956, two 55-gallon drums, with one end of each removed, were buried adjacent to each other at the evaporation station. The open ends of the drums extended two inches above the ground surface. Angle-iron supports for hook gauges were constructed across the open ends, and the pans were filled with water to the ground level. Thermocouples were inserted just below the water surfaces to give continuous measurements of water temperatures in each of the containers. One was filled with plain water and the second was given an application of one mg. of hexadecanol. Once-daily readings with hook gauges were made on both pans. Water losses from the two drums for the period

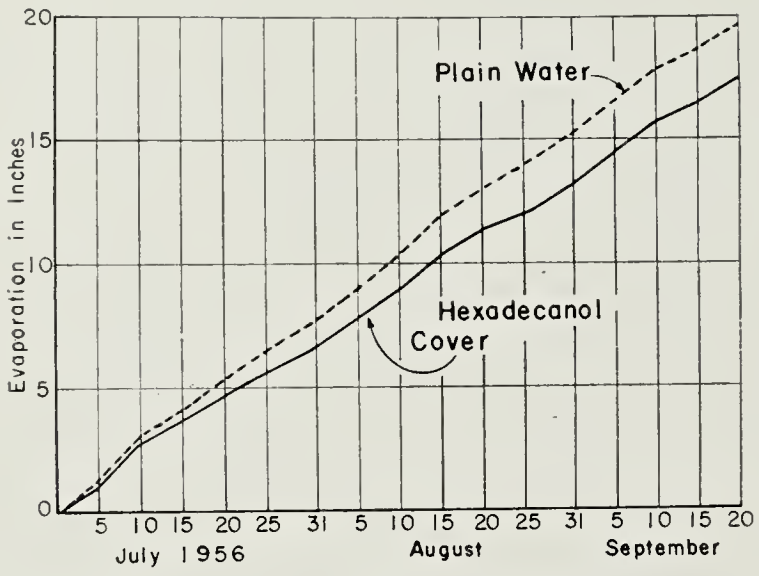

FIG. 2.—Cumulative evaporation from evaporimeter pans at Urbana, Illinois.

July 1 to September 20, 1956, differed by 27% as shown in Figure 4.

Although hexadecanol films are reported (Chem. Week, 1956) to allow free transfer of oxygen and carbon dioxide from the air through the film to the water, there was some evidence that the film had a retarding effect. Rust collected along the inside of the drum, filled with plain water, to a depth of six inches from the surface while less than one-inch of rusting was noted in the drum that had the monolayer covering.

In August, 1956, the University of Illinois made available for this project a 100,000-gallon capacity aerator tank located on the campus at Urbana. During August, September, and October, tests were made for water losses from this basin, using alternately plain-water surfaces and surfaces with monolayers. The water was changed before each treatment began.

Figure 5 shows the cumulative evaporation from the aerator tank and from a nearby Class A pan. During the period of record, August 15 to October 28, 1956, the Class A pan evaporation was 10.70 inches while the aerator tank evaporation measured 8.22 inches or 23% less. Some of this difference might be accounted for by the sizes of the containers.

During the periods marked A, B and C the aerator water surface was treated with hexadecanol. For the week of August 30 to September 7, evaporation from the aerator tank was 56% less than that from the Class A pan. Subtracting from this amount the over-all average difference of 23% leaves 33% credited to the evaporation suppression effect of hexadecanol. Similar credits of 24% and 11% are shown for the periods, September 14 to 23 and October 11 to 18. It can be seen that the evaporation suppression effect of the chemical becomes less as summer ends and fall weather begins. Sampling of the interim periods indicates close agreement between pan and aerator tank evaporation rates.

Close examination of the lower curve shows that efficiency of the chemical was highest during the first two or three days of application and dropped considerably during the latter part of each period. This would indicate that the method

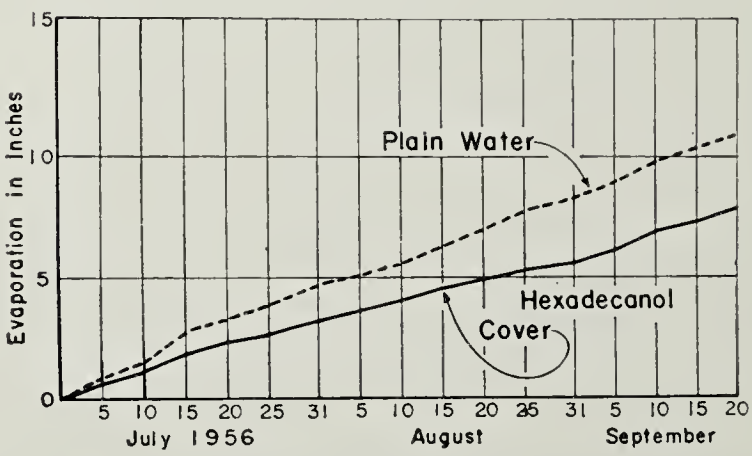

FIG. 3.—Cumulative evaporation from three-foot deep buried pans at Urbana, Illinois.

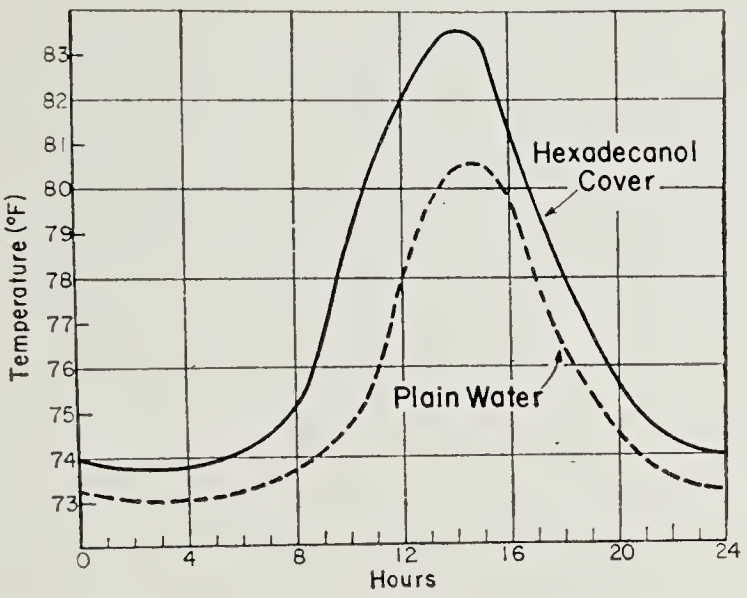

FIG. 4.—Surface water temperature curves for three-foot deep buried pans, one day after application of hexadecanol.

of applying the chemical needs to be greatly improved.

Figure 6 shows one section of the aerator tank including the hook gauge, temperature recorder, and the water level recorder.

Cost of retarding water evaporation.—The small quantity of chemical used so far in the Illinois research program has cost $2.10 per 500 gms., roughly $2.00 per lb. The Australians reported their cost for hexadecanol as 7s. per lb. or, at the present rate of exchange, 75 cents. The evaporation retardant material used in the Texas studies was reported to cost 40 cents per lb.

Dressler (unpubl. address, 1956) pointed out that the film-forming material accounts for two-thirds the cost of evaporation control treatment, with the remaining one-third charged to effort in getting the chemical on the water. The results of several research projects throughout the world indicate that the water saved is worth 20 or more times the cost of treatment, with indications that greatest savings could be effected if the treatment could be applied on larger water bodies.

Applying the film.—A total of four hexadecanol containers was used on the Illinois Water Survey's aerator tank. The containers had wooden bases 10″ long and wooden ends 4″ by 4″. The sides and tops were made of fine copper screen wire. The wire-mesh, floating container, one anchored in each acre of water area, has been the popular means in Australia, Africa, and the United States for getting the film on the water. This method of propagation is probably unsuitable for large-scale control of evaporation from lakes where there is considerable boat traffic.

It is suggested that boats could be one means of applying the monolayer to Illinois lakes and water supply reservoirs. On most large lakes a police boat regularly patrols the waters. A simple attachment on the water pump of the boat engine would channel a stream of water through a vessel containing the chemical and into the lake. The chemical would be spread by the wake of the boat and the area and schedule of seeding could be adjusted to the needs of the individual lakes.

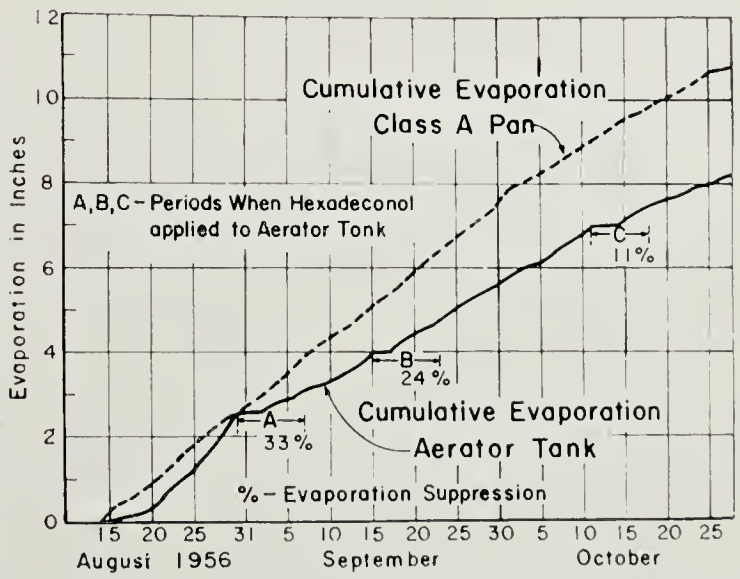

FIG. 5.—Evaporation from Class A pan and 100,000-gallon capacity aerator tank at Urbana, Illinois.

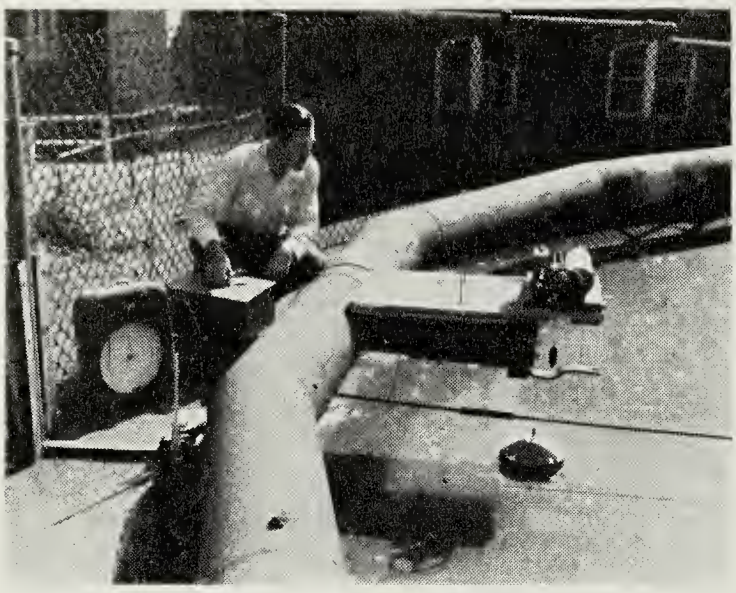

FIG. 6.—Aerator tank used to test monolayers at Urbana.

The program cost would be little more than the cost of chemicals. The labor expense would be absorbed in the cost of operating the patrol boat. A few floating containers may be necessary on the windward sections of the lakes to insure maximum effect of the monolayer. As the value of monolayer coverings becomes better known in the field of water resources management, the problems of developing practical and economical methods of producing the coverings will probably be quickly developed.

Toxicity and attrition of films.—According to Berger (pers. comm., 1957) film destruction by organisms in well-seeded natural water may be an important factor. Ludzack and Ettinger (1957) have found that emulsions of hexadecanol and pellets of the material suspended in baskets undergo biological destruction in laboratory test studies. They reported that, on two different runs at 20° C., suspensions of hexadecanol in very gently aerated carboys showed a weight loss averaging 3.5 and 4.3 lbs. per acre per week.

The statement (B. B. Berger, pers. comm., 1957) on toxicity of commercial preparations containing hexadecanol as prepared by the Robert A. Taft Sanitary Engineering Center has been accepted as a basis for Illinois tests, in the absence of direct evidence against hexadecanol as a hazard to health.

CONCLUSIONS

Although the Illinois State Water Survey evaporation suppression study has been in operation only a year, our experiences in this study confirm much that has been found experimentally elsewhere, although our findings appear to be generally more conservative. Most of the studies have been carried on in areas of the world where normal evaporation amounts are two or three times greater than those in Illinois. Under Illinois conditions the rate of natural water loss by evaporation may be reduced by a maximum of 33% during the warmest part of the summer and by about 11% during the cooler frost-free periods by application of hexadecanol. Many Illinois water supply reservoirs store nearly 50% of their capacity in the top 3 feet. Normal evaporation exceeds three feet per year in reservoirs in the southern half of the state where surface waters provide most municipal supplies. If evaporation could be reduced by one-third it would be equivalent to a 17% increase in Illinois reservoir storage capacity. During the summer of 1957, the program will be expanded to include studies on suppressing evaporation from larger water bodies and of problems encountered so far in our work in Illinois.

Acknowledgments

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TEACHING OF CONSERVATION OF NATURAL RESOURCES IN ILLINOIS COLLEGES AND UNIVERSITIES: A RE-APPRAISAL

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A decade ago Troy L. Pewe, a professor of geology at Augustana College, Rock Island, Illinois, presented a paper before this Academy on the "Teaching of Conservation of Natural Resources in Illinois Colleges and Universities." He reported that 13 of the 45 accredited four-year colleges and universities in our state, but not one of the junior colleges, offered a general course in conservation. According to Mr. Pewe, the University of Chicago has the distinction of being the first institution to initiate such a course. That was in 1909. His study also brought out the fact that in 12 of the 13 schools the course was taught in the department of geography.

It is now ten years later and time for a re-appraisal of the status of conservation education in the accredited institutions of higher learning in Illinois. Following the pattern set by the original study, all seminaries, technical schools, and special schools of art and music were eliminated from the survey. Course offerings were checked as listed in the official school catalogs for the academic year 1956-57. The following schools were offering a general course in the conservation of natural resources at the undergraduate level:

Institution	Department
University of Illinois (Urbana)	Geography
University of Illinois (Chicago)	Geography
Illinois State Normal University	Geography
Northern Illinois University	Geography
Eastern Illinois University	Geography
Western Illinois University	Geography and Geology
Southern Illinois University	Geography
Chicago Teachers College	Geography
University of Chicago	Geography
Northwestern University	Geography
Augustana College	Geography
Concordia Teachers College	Geography
Wheaton College	Geography
Rosary College	Geology and Geography
St. Precopius College	Biology
The Principia College	Biology
Joliet Junior College	Conservation

The results of this study emphasize the following:

1. At present, 16 colleges and universities or only one-third of all the accredited four-year institutions of higher learning in our state offer a general course in the conservation of our natural resources. The schools which did not appear in the original list ten years ago are: University of Illinois at Urbana, University of Illinois at Chicago(Navy Pier), St. Precopius College, and

Wheaton College. In addition, one junior college now offers such a course. It is true that the University of Illinois at Urbana did offer courses in conservation ten years ago, but they were advanced courses or of such a technical nature that they were not intended for the general undergraduate student. One college listed in the original survey and not appearing in the present listing is McKendree College at Lebanon, which reportedly dropped the course because of limited staff. General conservation courses at Northwestern, whenever they were offered, were taught only in the summer, but none are scheduled for the 1957 summer session. We must conclude, then, that the actual institutional gains have been very slight.

2. General conservation courses are still largely taught in geography departments. St. Precopius and The Principia are the only colleges in which such a course is taught in the biology department; in Rosary College the course is taught in the geology and geography department but the same course may be taken for biology credit. The biology department at Shurtleff College gave a course in the conservation of biological raw materials, but because of this restrictive terminology it was not included in this survey.

3. The greatest variety of conservation courses is given in our state supported institutions, especially in the former teachers colleges. Some of them offer conservation clinics or special courses for in-service teachers during the summer sessions. The state universities and the University of Chicago also offer advanced work in resource management and resource problems.

Mr. Pewe closed his article with the following observation (1947: 115), "Illinois with its tremendous wealth of natural resources and its wonderful colleges and universities, should be one of the leading states in education of conservation of natural resources. The students of the nation should be taught the importance of conservation of natural resources by being required to take at least a general course during their college days. It is the educators' duty to see that the youth is informed of the importance of conservation to insure our national heritage for future generations."

In view of the findings presented in this paper I wonder whether conservation education in Illinois colleges and universities has really made any great advance during the last decade. If we agree with Mr. Pewe, that conservation education is essential to the well-being of our state and nation, then we must be willing to take the initiative in the fight for more conservation education in our institutions of higher learning. The present situation indicates that one of the greatest strengths of conservation courses lies in the training of elementary and secondary teachers. Would it be logical to insist that every prospective teacher in our public school system take at least one course in the conservation of natural resources before a teaching certificate is issued? Practically every college in our state has a teachers' training program, but the majority of them

do not offer any courses in conservation. This might be the path we must explore in the next decade.

Summary

There has been very little gain in the number of colleges and universities which offer courses in the conservation of natural resources. It is, of course, highly probable that much incidental teaching is done on some aspect of conservation in connection with other courses. A concerted effort is needed, however, to acquaint our elementary and secondary teachers with the philosophies and problems of conservation.

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FORECASTING EXPLOSION CONDITIONS IN COAL MINES

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That depressions in atmospheric pressure result in increased emission of methane in coal mines is a well-known fact. That the same depressions, when followed by cold, dry air masses, produce a rapid loss of moisture from coal dust is a more recently recognized relationship (McIntosh, 1957). Increasing methane content and drying coal dust are conditioned changes toward greater risk of methane or coal-dust explosions. Knowledge of the magnitude of these changes in content of methane and moisture in coal dust could be of some importance in the coal-mining industry, particularly where the variation in explosive elements is great.

This paper presents a simple method by which a mine superintendent could determine the approximate increase in methane accompanying a predicted low atmospheric pressure. Furthermore, suggestions are made for continuing research into forecasting possibilities associated with the drying of coal dust.

Coal fields are found throughout the United States under varying climatic conditions. Explosions have occurred in all major fields. The forecasting information presented here pertains primarily to the Eastern Region of the Interior Coal Province which includes the Illinois coal fields.

The methane and coal-dust research studies were made in Peabody Coal Company mines No. 14 and No. 17.

Forecasting Methane Content

The meteorological aspects of the forecasting procedure must, of course, be left in the hands either of the United States Weather Bureau or of private industrial forecasters. A few words about the general weather conditions should suffice here.

Low pressure cells that produce depressions over the Eastern Region of the Interior Coal Province have their source of origin or regeneration along the eastern margin of the Rocky Mountains. This region on the High Plains to the east of the Rocky Mountains is often broken into three or four separate areas and called the Alberta source, the Colorado source, and the Southwest source. In reality, this linear region is a continuous north-south zone of cyclogenesis.

The barogram record from a barograph operated in Marion, Illinois, was inspected for drops in pressure of one-half inch or more over a 36-hour period. Any such drop in pressure would result in a marked increase in methane content of mine atmosphere. The Marion record covered a period from September,

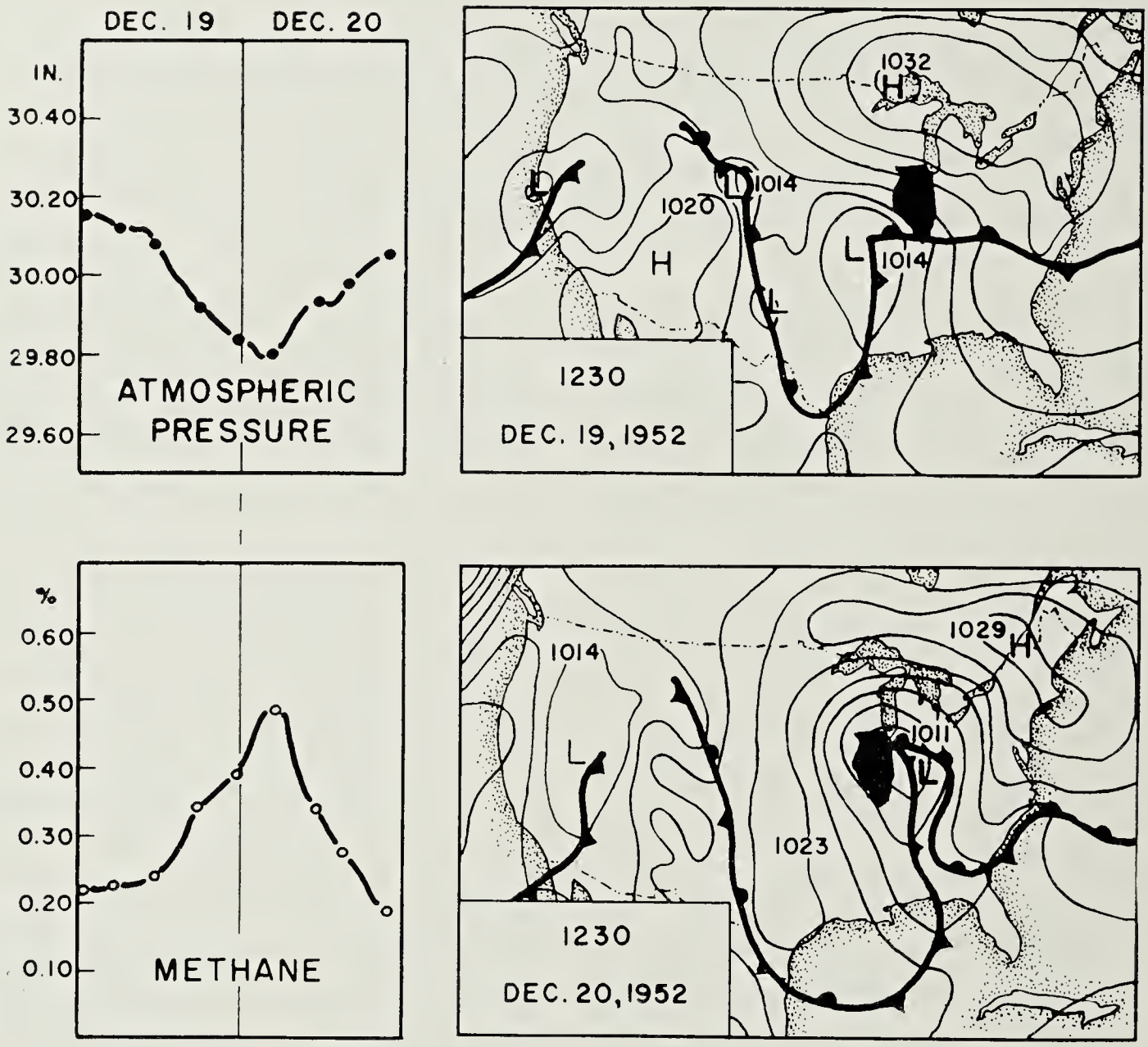


FIG. 1.—Atmospheric-pressure-methane relationship in southern Illinois coal mine.

1939, into November, 1952. Synoptic weather maps were available for 37 of the depressions marked by at least one-half inch fall in pressure. The source region of the 37 cyclones is shown in Table 1. This table indicates that cyclones producing significant drops in barometric pressure over southern Illinois come more often from the Texas and Colorado source regions than from farther north.

The effect of a drop in atmospheric pressure over a southern Illinois mine is illustrated in Figure 1. The weather maps in this figure show a deepening low moving from the southwest toward the northeast across Illinois. Microbarographs, on research loan from the U. S. Weather Bureau, were located in a mine entry at the point where air samples were taken and on the surface a short distance from the mine shaft. These recording instruments were used by the author to obtain the pressure trace shown in the upper of the accompanying graphs. The upper graph indicates the depression of atmospheric pressure at the mine, resulting from the cyclonic passage. The lower graph shows the change in methane content of the mine air as the cyclone passed over the mine.

TABLE 1.—Source of Deep Lows Observed in Southern Illinois Coal Field 1939-1952.

Source of low	Number of lows
Southwest	15
Colorado	11
Wyoming and Montana	5
Alberta	6
Total	37

The rising and lowering atmospheric pressures produce changes in methane content because of the pressure differential set up in the mine between entries and methane storage cavities. The term "methane storage cavities" as used here refers to rooms with permanent or temporary stoppings, crevices, fissures, and other places where methane may accumulate with little disturbance from ventilating air.

Falling air pressure at the surface is accompanied by a like pressure change in air ventilating the mine. The result is lower air pressure in mine entries and working spaces than in adjacent, sealed-off rooms. During such periods air moves from methane storage cavities to entries, bringing with it a high methane content characteristic of the atmosphere in the cavities. When atmospheric pressure in the entries is high there is a tendency for air to infiltrate the methane storage cavities.

The relationship between atmospheric pressure and the methane content of mine atmosphere is shown in Figure 2. The methane content of the 72 air samples shown in Figure 2 represents the total sampling used in this research work. All samples were taken from the same spot in the main return entry about one-half mile from the air outlet. Most sampling was started as a cyclonic depression approached southern Illinois and was continued during the ensuing fall and rise in pressure. Sampling on occasion, however, was continued through anticyclonic periods and thus represented both cyclonic and anticyclonic conditions. An attempt was made to obtain air samples at six-hour intervals, but the intervals varied somewhat depending upon accessibility of the sampling spot.

The overall arrangement of dots in the scatter diagram gives an inverse ratio, with higher methane readings associated with lower pressure readings. Close observation reveals that the alignment of dots is not a straight line. Little increase is noted in methane content as one follows the dot pattern from higher to lower pressures until the pressure level between 29.9″ and 30.0″ is reached. Below this pressure zone there is a more marked increase in methane per unit change in pressure than observed at higher pressures. The zone between 29.9″ and 30.0″ is a pivotal or fulcrum zone determined by the average atmospheric pressure for the elevation of the

TABLE 2.—Loss of Life in Dry-Air Explosions.

Explosion number	Number of persons killed
I	5
II	52
III	33
IV	111
V	119

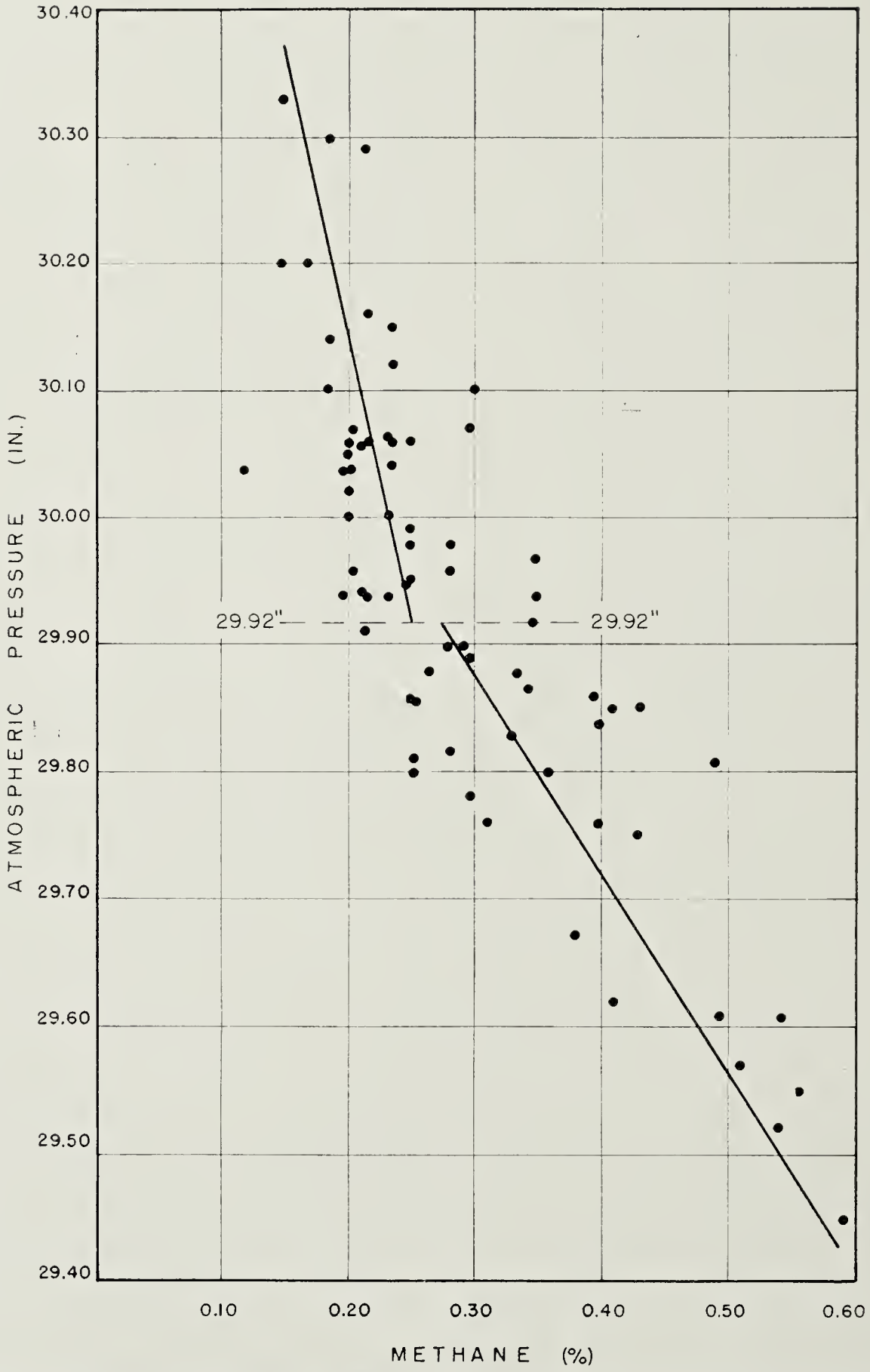


FIG. 2.—Scatter diagram of methane content from research coal mine.

research coal seam. The coal seam was almost exactly at sea level. Average sea-level pressure is 29.92″ and, since this figure fits into the pressure range of the pivotal zone, it was used as the pivotal point where the pressure differential changes direction. Above this point the average atmospheric pressure in the entries tends to be greater than in the storage cavities, and below 29.92″ the average pressure in the entries tends to be less than in the methane storage cavities. The lines of regression plotted for points found above and below the dividing

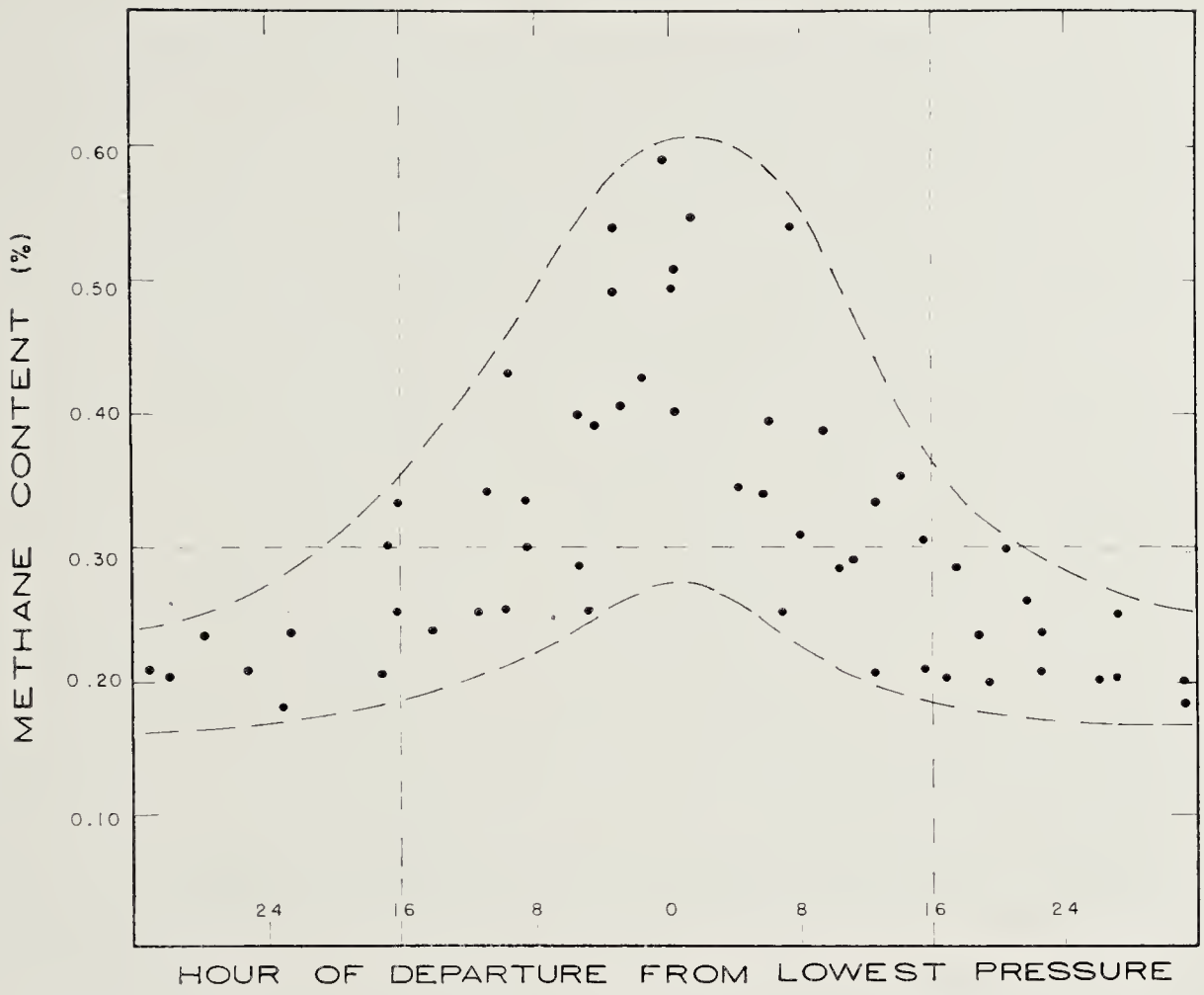


FIG. 3.—Duration of "gassy" classification in main return entry.

pressure-level help one visualize the above-mentioned difference.

A mine is classified as gassy when the mine atmosphere is found to contain methane in excess of 0.25% (Coal Mining Act, 1953). Ventilation of mines is thus set to keep the methane content close to or below the gassy classification. Actually, there are few non-gassy mines. Note in Figure 2 that the lines of regression depart from the selected pivotal pressure-level slightly above the 0.25% content. Below the pivotal pressure-level the line of regression indicates a methane content above the gassy classification.

Dots in Figure 3 represent the methane content in 57 of the 72 previously-shown air samples taken from the southern Illinois coal mine during the passage of 7 distinct atmospheric low-pressure cells or troughs. The methane content in the return air of the mine is shown along the vertical axis. The horizontal axis is a time scale in hours diverging from the time of lowest pressure indicated on the scale as zero (0). Dots have been placed to the left or right of zero in accordance with the time departure from zero hour.

The methane content in this mine moved into the gassy classification as much as 24 hours before the time of lowest pressure. The progression from non-gassy to gassy classification, however, came most often from 8 to 16 hours before the low-pressure passage, and this gassy classification continued for approximately the same length of time after zero hour.

The graphical tool used in forecasting the increase of methane in a mine is illustrated in Figure 4. The solid line M is the line of regression determined from the pres-

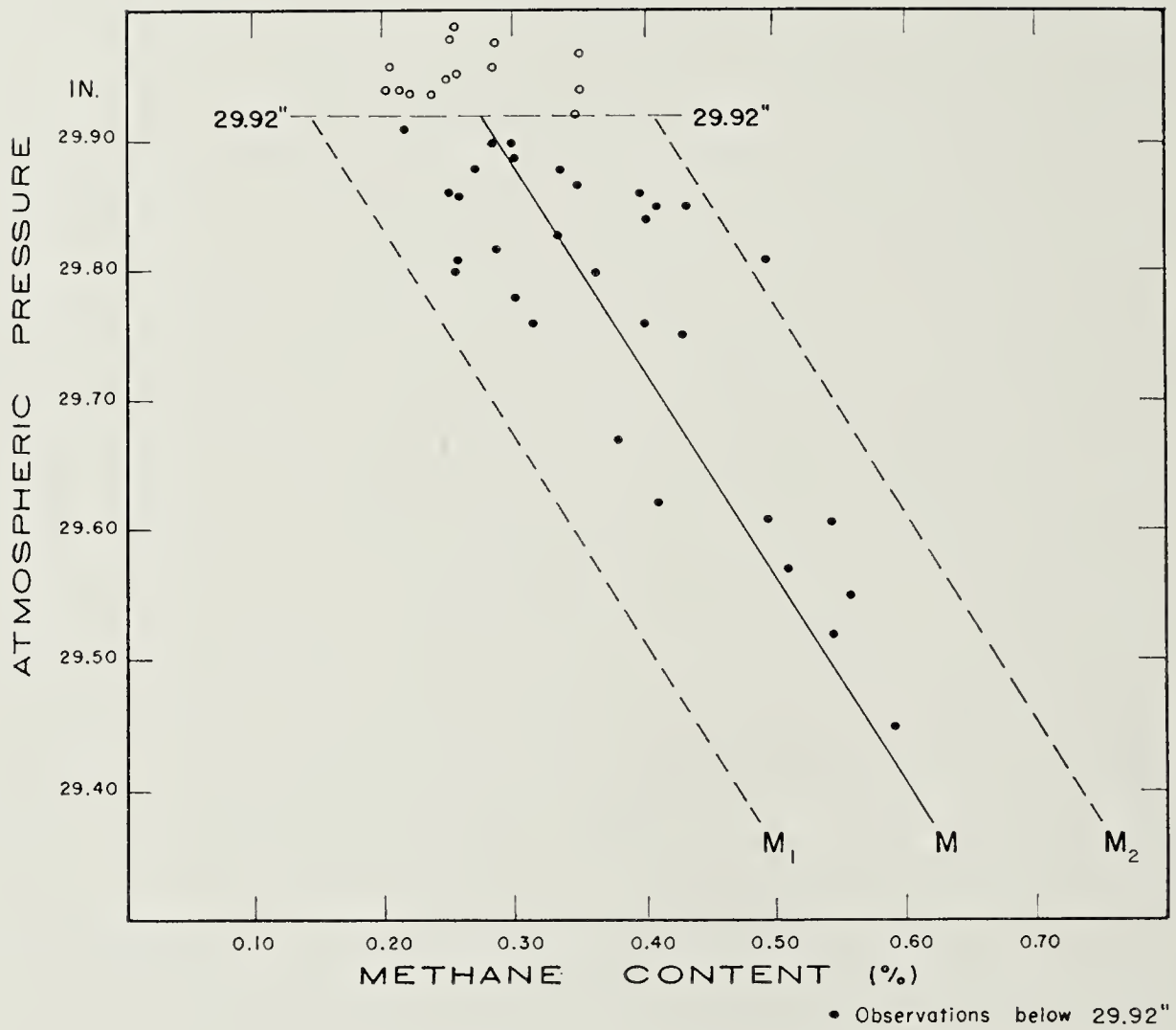


FIG. 4.—Chart used in determining methane content for a forecast low pressure.

sure and methane statistics for the methane amounts noted below the pivotal pressure of 29.92″ in Figure 2. Given a forecast of low pressure, the best estimate of methane content will be found along line M, and between the dashed lines, M_1 and M_2, 95% of the time.

Given (1) the time of low passage, and (2) the forecast barometric depression, the mine superintendent, by observing the time when the barometer drops below the pivotal pressure, may determine the approximate duration of gassy conditions and percentage of methane content at the time of lowest pressure.

A mine superintendent could use a simple inverted T-scale to plot the probable increase in methane. An example of such a construction is pictured in Figure 5. For example, the time of low-pressure passage over the mine is forecast for 9:00 p.m. This time is represented on the time scale by zero (0) hour. The atmospheric pressure falls below the pivotal pressure for the mine at 6:00 a.m. on the day of the expected low pressure. The 15 hours representing the time difference between 6:00 a.m. and 9:00 p.m. is marked off to the left of zero hour. The pressure forecast calls for a reading of 29.50″. The expected methane content is found as shown (Fig. 5, "B") by moving horizontally from the forecast pressure of 29.50″ to the line of regression M, and then dropping vertically to the methane scale. The methane scale indicates a reading of 0.53%. This reading is marked on the vertical axis of Figure 5 (A) and forecast

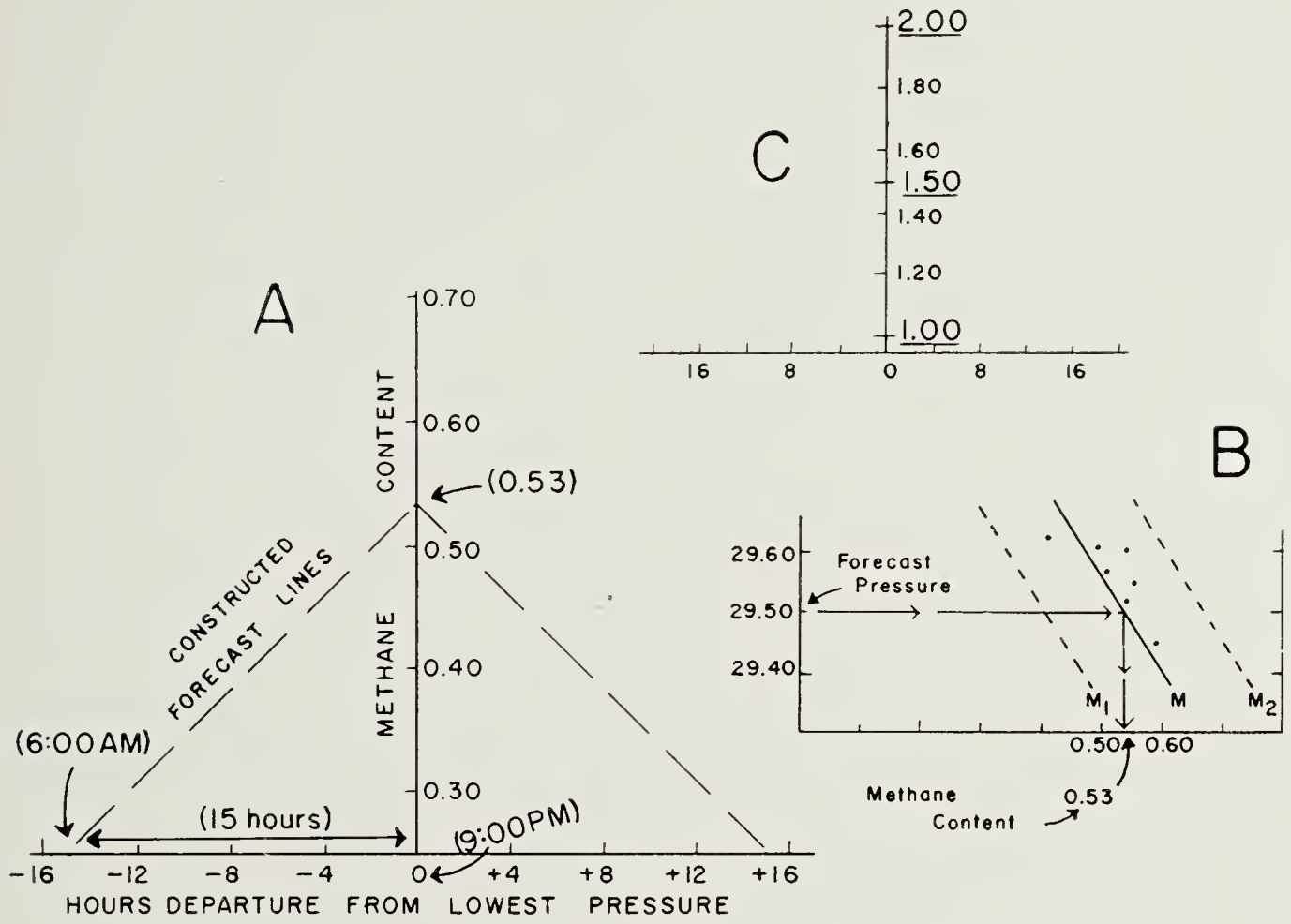


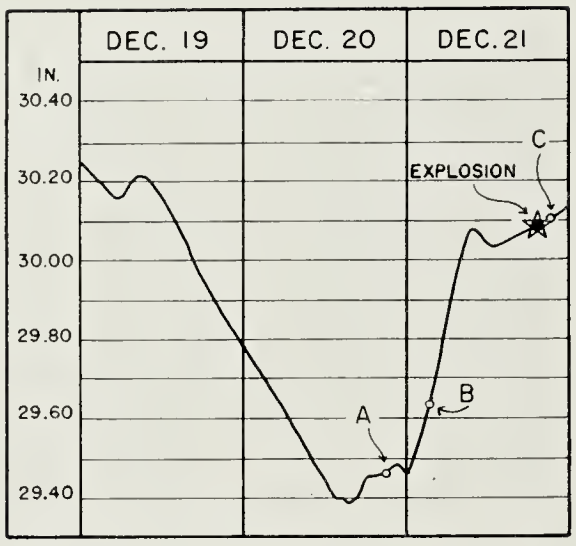
FIG. 5.—Chart used in diagramming forecast conditions.

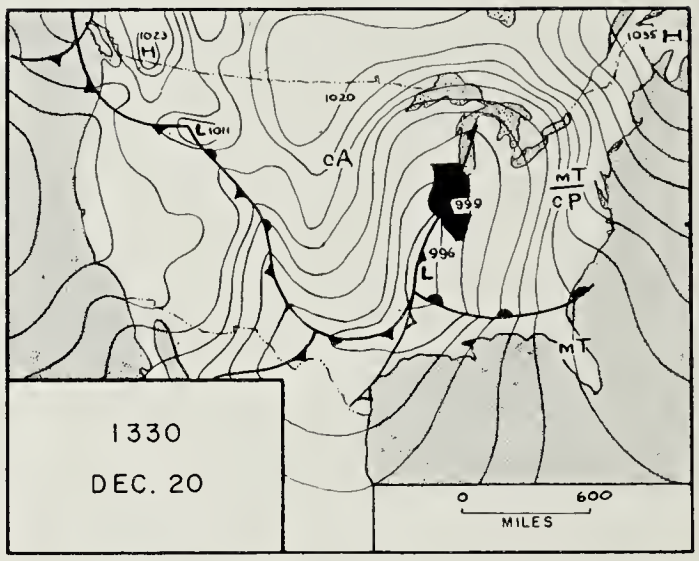
lines drawn to minus 15 hours and plus 15 hours on the horizontal time scale. Such a graph would indicate a gassy mine condition from 6:00 a.m. one day until noon the following day with a maximum methane content of 0.53% at 9:00 p.m.

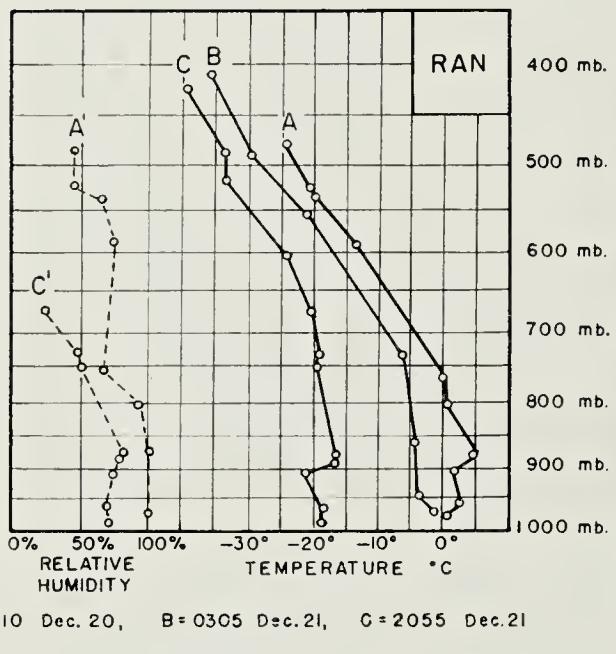
Some areas in mines, because of technical or natural reasons, have an unusually high methane content even under normal working conditions. Such areas are inherently dangerous during an atmospheric depression. These areas should have special attention in methane testing and forecasting. Scatter diagrams can be drawn from these more limited areas and special forecasting graphs with higher readings on the methane scale, as in Figure 5 (C), could be used to make forecast plottings. The readings of 1.0, 1.5, and 2.0% have been emphasized because of the significance associated with these figures as noted in the Illinois Coal Mining Act (1953) in connection with extreme precautions and removal of men from areas having such high methane content. Every mine has its own individual characteristics. The scatter diagram discussed here would be valid only for the mine from which the air samples were taken.

Coal-Dust Danger Period

Experimentation in two Illinois coal mines has established the fact that change in air masses, when the second air mass is cold and dry, results in a rapid loss of moisture from coal dust. Research with the coal dust has indicated a loss of from 7 to 11% of the total moisture content in coal dust within 24 to 36 hours after such a change occurs. Such a loss of moisture from







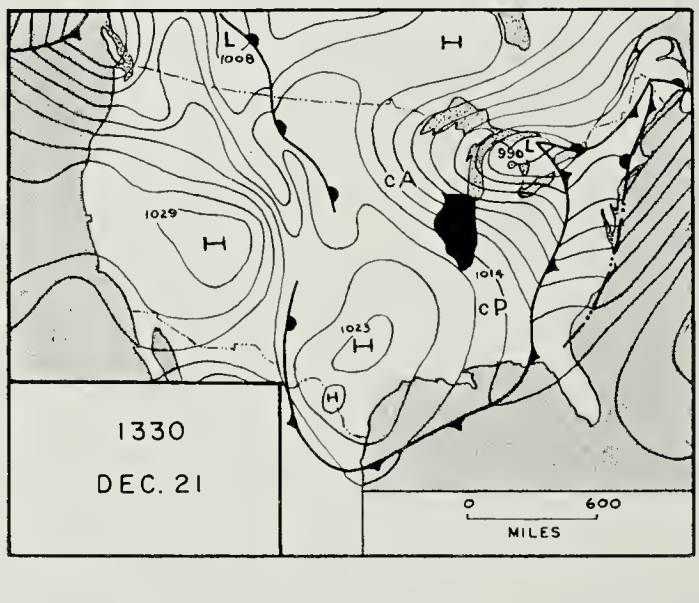


Fig. 6.—Weather charts for the 1951 West Frankfort explosion.

coal dust permits the dust to be more easily dispersed into the air, where it may be ignited.

Coal-dust explosions result in more extensive mine damage and generally greater loss of life than explosions resulting from methane gas only.

With these facts in mind we may take a look at some relationships between weather, coal dust, and mine explosions. Figure 6 pictures weather maps for December 20 and 21, 1951, with two accompanying charts. The upper chart represents the barogram trace from a weather station near the location of a coal-mine explosion. The lower chart pictures the radiosonde information for December 20 and 21, 1951. The barogram trace and maps show the low-pressure area passing over Illinois late on December 20. The explosion took place late December 21.

Lapse rates, A, B, C, plotted from Rantoul radiosonde observations were taken at the times shown by letters and arrows along the barogram trace in the upper chart. The 24 hours elapsing between A and C brought a drop in surface temperature of 36.7° F. The loss in the air-mass temperature is evident at all elevations.

The relative humidity dropped from 100 to 72% during the 24 hours between A and C. Although this lowering of the relative humidity gives some indication of a drop in air moisture, the true moisture loss

is masked by the accompanying drop in temperature. The vapor pressure at the time of A was 0.203″; it dropped to 0.024″ at the time of C. With such a drop in vapor pressure, loss of moisture from the coal dust should have been considerable. The large area of destruction in the mine was evidence of the important part coal dust played in spreading the explosion from the point of ignition.

Coal-mine explosions occurring since the advent of the radiosonde are limited in number. But one of the first steps in determining forecasting possibilities associated with danger periods in coal dust would be to make a thorough investigation of the radiosonde information available for these few coal-mine explosions.

Samples of the atmospheric pressure patterns similar to those mentioned above are presented in Figure 7. The barograms are all associated with mine explosions in the Eastern Region of the Interior Coal Province. In each of the cases shown, the explosion occurred between 22 and 28 hours after the time of lowest pressure. Cold air masses followed the low pressure, placing the mines under the influence of cold, dry air approximately 24 hours before the explosions. Four of the five explosions associated with the pressure patterns shown in Figure 7 resulted in a large loss of life (Table 2).

Thus, we find similarity not only in the weather and time relationships, but also in the generally high loss of life in these explosions.

Number IV and Number V in Figure 7 represent the barograph traces for the Centralia (1947) and the West Frankfort (1951) explosions. Both of these explosions took place under mining practices prevailing at the present time. The pressure fell a little more than 0.7″ in one case (includes .34″ fall during last 13 hours of March 22) and 0.8″ in the other. In both instances the lowest pressure was approximately the same. Both explosions took place about 28 hours after the lowest pressure and when the pressure had risen to 30.06 to 30.08″. In both cases the vapor pressure had been below normal during one of the three days prior to E day, had fallen below 0.080″ on the day of the explosion, and remained low during the following three days. And in both cases more than 110 lives were lost.

The vapor-pressure changes associated with the Centralia and West Frankfort explosion periods are shown in Figure 8. Water-vapor content of the air on both explosion days is far below normal. There must have been rapid drying of coal dust within that part of the mine affected by the dry, cold air.

Much more research needs to be done in connection with the effect of air-mass exchange upon coal-dust moisture. The relation of moisture to dispersibility of dust, however, is not the only line of research awaiting attention. For instance, there is some indication of differences in the development of static electricity under conditions of moist air and dry air. Some theories set forth the idea that explosions have an electric origin rather than a thermal one (Hartmann, 1954). The drying period following a cold frontal passage could be a period of rapid increase in static electricity on the

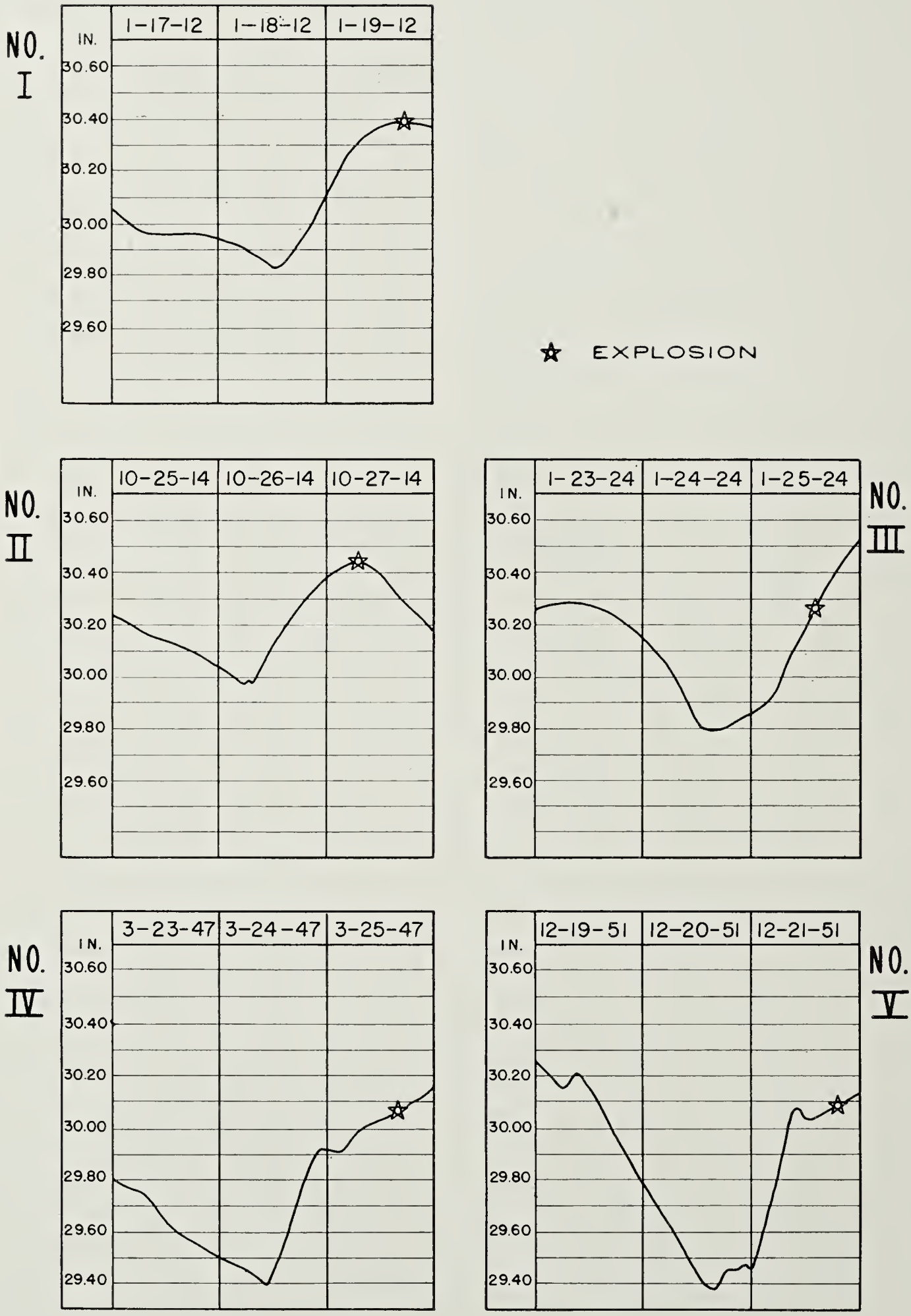


FIG. 7.—Pressure patterns of post-frontal explosions.

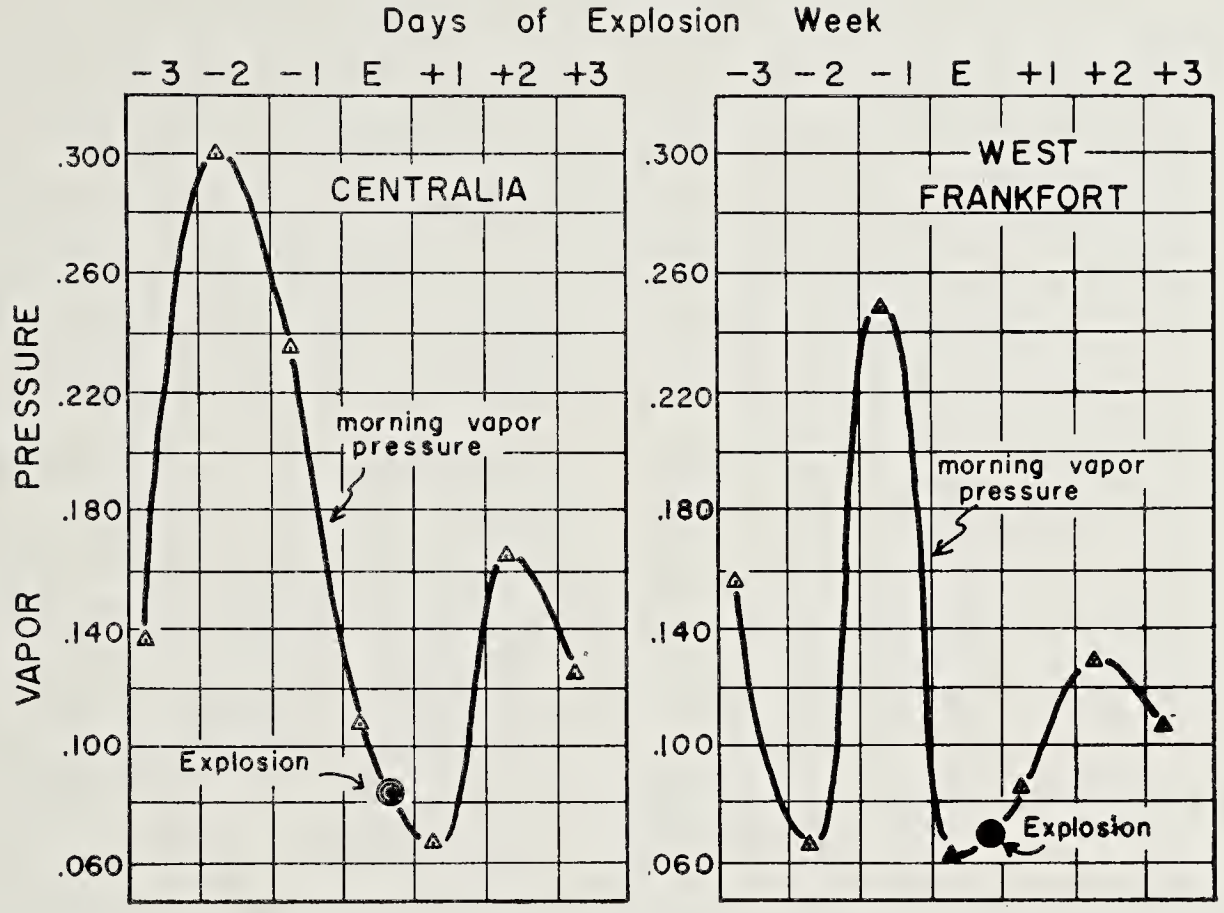


FIG. 8.—Vapor-pressure patterns for the Centralia and West Frankfort explosions.

coal dust. It might not be out of place to suggest an investigation of this aspect in relation to a possible connection with explosions.

SUMMARY

The establishment of a regression line on a scatter diagram of methane observations may be used to forecast periods of excessive methane content in coal mines. Given the time of an expected low-pressure passage and the lowest associated pressure, the mine superintendent may determine the duration of gassy mine conditions, the time of greatest methane content, and the maximum amount of methane expected.

Dangerous coal-dust conditions are seemingly closely associated with post-cold frontal drying. More work must be done in connection with relationships between water vapor of the air, coal-dust moisture, coal-dust dispersion, and possibly with the development of static electricity, before a system of forecasting dangerous coal-dust conditions can be established.

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THE CHANGING PETROLEUM INDUSTRY OF WESTERN EUROPE

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Since the industrial revolution, the countries of Europe have relied almost totally upon coal as the source of industrial energy. This dependence upon coal tended to retard the use of petroleum as an energy-producer. After World War II, however, petroleum increased in importance. This growth was associated with: 1) growing problems of the European coal industry; 2) inherent advantages of petroleum as an energy-producer; 3) increased demand for energy; and 4) need for increased productivity per man.

Before World War II extensive petroleum processing centers were neither required nor desirable for greatest efficiency. The bulk of the products consumed was processed petroleum commodities of high value, and little emphasis was placed on the utilization of by-products. Refineries were, in general, located near the source area of the crude oil. The crude was processed, and the products of high value were shipped to market in a finished state. In 1938 less than one-third of the processed petroleum products consumed in Western Europe were refined in the marketing areas (Fig. 1). (O.E.E.C., 1955: 13). The dominant source for refined products and crude oil at this time was the Western Hemisphere.

World War II and the resulting technological achievements acted as catalysts on the petroleum industry of Europe (Table 1). The increasing demand for petroleum products, however, presented serious problems. The major immediate problem facing the nations of Europe was to supply petroleum products without damaging the countries' weakened economies. In an effort to solve this problem, among others, 17 nations joined together to form the Organization for European Economic Cooperation. Working in conjunction with the United Nations and the Marshall Plan, the organization had as its immediate purpose the integration of the expansion programs of the member nations. (Hereafter the member nations of the O.E.E.C. indicated on Fig. 1 will be referred to as "Western Europe.")

It was apparent to the member nations of the O.E.E.C. that, if they were to utilize greater amounts of petroleum, the pre-war system of marketing would have to be altered. The aims of the nations were: 1) to lower costs of petroleum products, since their buying power, especially in dollars, was limited; and 2) to create a system of marketing that would make each country as immune as possible to future stra-

FIG. 1.—O. E. E. C. member nations of Western Europe.

tegic and political problems. The means for achieving these aims seemed to be the location of refinery facilities in the market rather than the source area.

Five major economic factors favored greater emphasis on market area refineries. 1) Market area refineries eliminated the expense of foreign refining. 2) Market area refineries actually increased the total assets of the countries through the value of the industry itself and the employment it created. 3) Market area refineries lessened shipping and storage problems which had previously accompanied the importation of refined products. 4) Market area refineries permitted a country to market finished or refined products,

TABLE 1.—Proportion of Energy Supplied by Petroleum.[1]

Year	Percentages	
	World	Europe
1938.....	20	8
1949.....	30	11
1955.....	37	18

[1] From O.E.E.C. (1955: 13).

creating an additional source of income. 5) Capital was made available through various reconstruction agencies.

Three major strategic and political factors fortunately complemented the economic factors. 1) The establishment of refineries at the market area permitted the purchase of crude petroleum from any available source and eliminated complete dependence upon one area for specific petroleum products and raw materials. 2) The current trends of nationalism and anti-colonialism create unstable conditions for development of source area refineries outside the political realm of the investor. 3) In national emergencies market area refineries can be more efficiently protected and defended.

Petroleum's Growing Importance in Post-war Europe

Western Europe has increased the total crude oil processed by refineries from 14,000,000 metric tons in 1938 to 103,000,000 metric tons in 1955 (O.E.E.C., 1955: 23, 78). These figures not only indicate expansion of refining capacities but also increased consumption (Table 2). The consumption of refined petroleum products increased at an average of 13.2% a year during reconstruction, with a total increase of approximately 270% in 1955 over 1947. During the same period Western Europe increased its petroleum refining capacity from less than one-third of the total amount of crude oil imported in 1948 to more than nine-tenths of the total amount of crude oil imported in 1955.

As refining in market areas grew in importance, significant changes occurred in source areas. In less than ten years the flow of crude petroleum and finished products into Europe shifted largely from the Western Hemisphere to the Middle East. Between 1938 and 1955 the Middle East increased its shipments to Europe more than ten-fold. In 1955 the Middle East accounted for 80% of the crude and finished products entering Western Europe (Table 3). In contrast, the West-

TABLE 2.—Output of Refined Products and Total Consumption of Petroleum Products (in million metric tons).[1]

Year	Output by refineries	Consumption, O.E.E.C. Europe	Refin. prod./consumption
1938...	12.5[2]	39.0[2]	32.3%
1947...	10.9	37.1	29.6
1948...	17.5	39.9	43.9
1949...	26.0	46.8	55.6
1950...	36.8	55.0	66.9
1951...	53.9	65.8	81.9
1952...	68.0	69.6	97.7
1953...	77.2	75.0	102.9
1954...	88.6	86.8	102.1
1955...	94.2	99.9	94.3

[1] From O.E.E.C. (1955: 78).
[2] Estimate.

TABLE 3.—Total Petroleum Imports into Western Europe (in million metric tons).[1]

From	1938	1950	1955
Middle East	8	40	90
Western Hemisphere	26	16	21
Others	5	..	2
Total	39	56	113

[1] From O.E.E.C. (1955: 46).

ern Hemisphere in 1938 shipped 66% of the products consumed by the member nations.

The growth in refining capacities developed at the same time as the shift in source areas. Through economic cooperation the member nations of the O.E.E.C. concentrated on the construction and expansion of refineries within their political boundaries. With the increasing demand for refined products, the existing refineries in the source areas continued to function on efficient levels, but there was an increase in capacity and production of market area refineries.

The emphasis in the expansion program was on efficiency and economy of production. These objectives resulted in the actual abandonment of some refineries which were deemed relatively inefficient and the expansion or construction of larger and more efficient refineries. The output by refineries in Western Europe between 1950 and 1955 was more than doubled, but the actual number of refineries decreased slightly (Tables 2 and 4). The petroleum industry of France illustrates this trend. In 1941 the country had 19 operating refineries, but in 1955 the number had decreased to 13. Yet, production capacity increased three-fold. Italy was the only country which experienced an increase in the number of refineries between 1950 and 1955 (Table 4).

A more precise index to the growth of refineries is the actual capacity of the industry (Fig. 2). The United Kingdom (30%), France (23%), and Italy (18%) command 71% of the total refining capacity (Table 5). The greatest relative increase in capacity between 1950 and 1954 was experienced by Belgium. With the exception of Ireland and Norway, the member nations experienced substantial increases in capacity between 1950 and 1954; yet there was a decline in the total number of refineries. It is apparent that refinery capacities are being increased to permit lower production costs per unit.

The changing flow patterns and refinery expansion of Western Eur-

TABLE 4.—Major Refineries Operating in Western Europe.[1]

Country	1941	1950	1955
Austria	5	9	7
Belgium	7	7	7
France	19	16	13
Germany	53	26[2]	20[2]
Italy	10	16	35
Netherlands	1	2	2
Portugal	1	1	1
Sweden	1	4	2
United Kingdom	18	21	14
Others (Denmark, Norway, Switzerland, Turkey)	4	5	3
Total	119	105	104

[1] From O.E.E.C. (1955: 78) and Amer. Petrol. Inst. (1951: 454, 456).
[2] Western Germany.

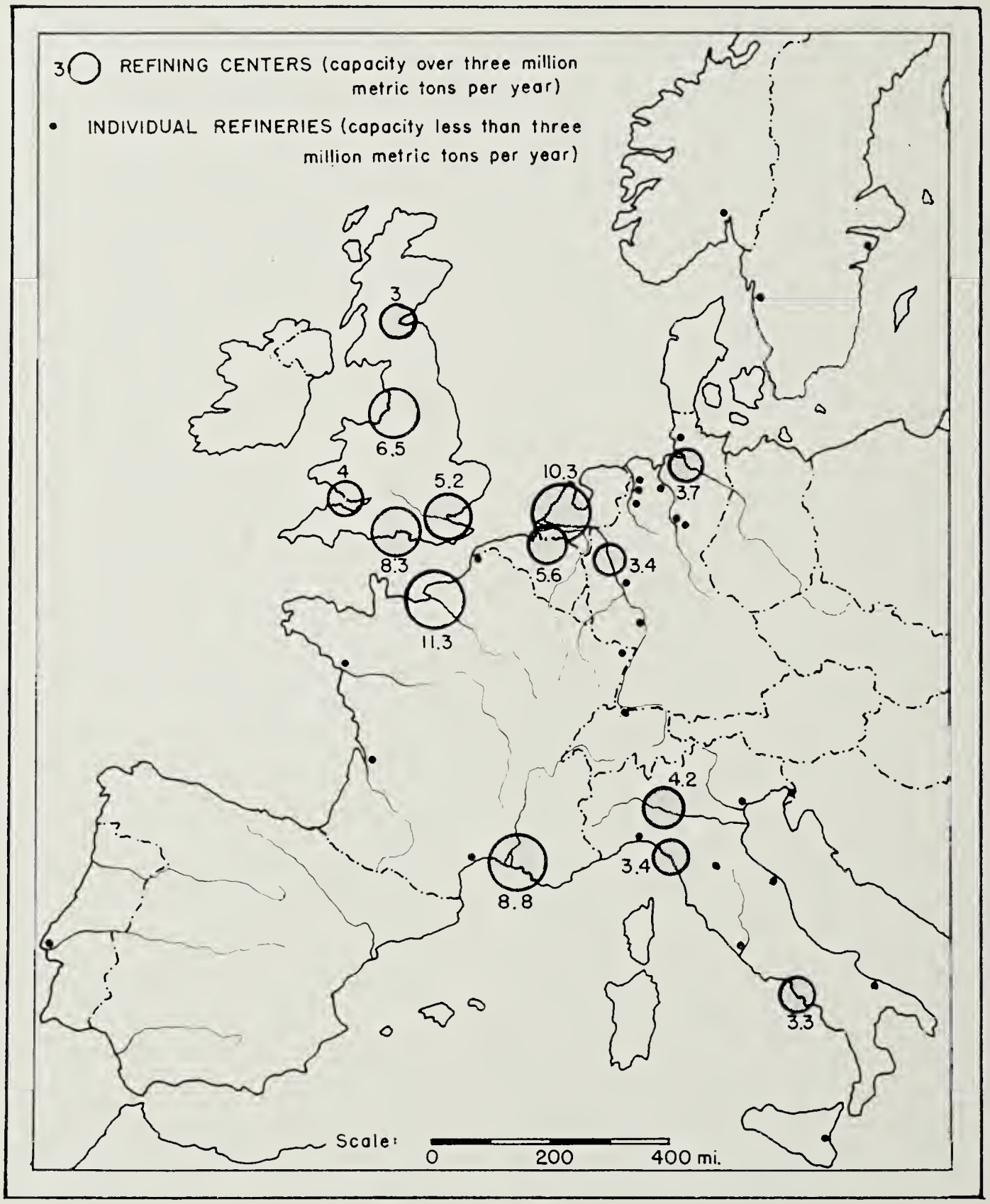

Fig. 2.—Major refineries of Western Europe (1955).

ope is illustrated in Figures 3 and 4. Although the increase in production may be the most striking contrast, a comparison of the crude imports and refined imports of 1948 with those of 1955 reveals an important aspect of the changing structure of Western Europe's petroleum marketing system.

Location and Transportation

Two primary factors in the location of petroleum refineries in Western Europe are transportation facilities and market. Most of the refineries are near the sea, and the few inland refineries are oriented to rivers (Fig. 2). The extensive de-

TABLE 5.—Refinery Capacities of O.E.E.C. Member Nations (in thousand metric tons).[1]

Country	1941	1950	1954
Austria	401	1,305	.....[3]
Belgium	609	790	4,765
Denmark	250	31	45
France	7,578	15,285	22,825
Germany	3,038	3,557[2]	9,955[2]
Ireland	530	30	00
Italy	2,865	5,360	17,940
Netherlands	750	3,850	9,925
Norway	60	50	50
Portugal	250	375	1,250
Sweden	175	1,290	1,740
Switzerland	.....[3]	00	200
United Kingdom	6,673	9,838	30,033
Total	23,179	41,761	98,628

[1] From Amer. Petrol. Inst. (1951: 454, 456) and (1954: 494).
[2] Western Germany.
[3] Figures not available.

velopment of the petroleum industry in Belgium and the Netherlands, for example, has been complemented by their favorable locations. The refineries in both countries import crude by means of ocean-going tankers, process the raw material, and market refined products in their own countries and at available markets on the Rhine. The distance between the source area and the processing center also affects the location of refineries. This factor has encouraged France to develop two major refining centers, one on the Atlantic coast near the major consuming areas and one on the Mediterranean oriented towards the source area.

The bulk of petroleum products imported by Western Europe is shipped by ocean-going vessels. Although the costs of water transportation are relatively low, current problems concerning the Suez Canal and the limitations of tankers have renewed interest in the movement of petroleum by pipelines from the source area to the markets. But political fragmentation of Europe and the Middle East, combined with international political philosophies, discourages such a program at the present. Nevertheless, with the increased efficiency of movement by pipelines, some advances may be made in or between political units of the O.E.E.C. Since it is now possible to transport more than one commodity by pipeline, countries like France and Germany may utilize this method for greater efficiency of movement between refinery and consuming areas.

SUMMARY AND PROSPECT

The function and structure of the petroleum industry of Western Europe reveal two significant changes which have occurred since World War II. 1) The dominant source area for petroleum has changed from the Western Hemisphere to the Middle East, and the bulk of the products shipped has become crude petroleum rather than refined commodities. 2) Since World War II, consumption of petroleum has increased substantially, even though there has been an actual decrease in the number of operating refineries.

The growth of the petroleum industry in Western Europe is applicable to Prescott's concept of growth related to demand and to White and Foscue's concept of manufacturing stages (Prescott, 1922: 471-479; White and Foscue, 1955:

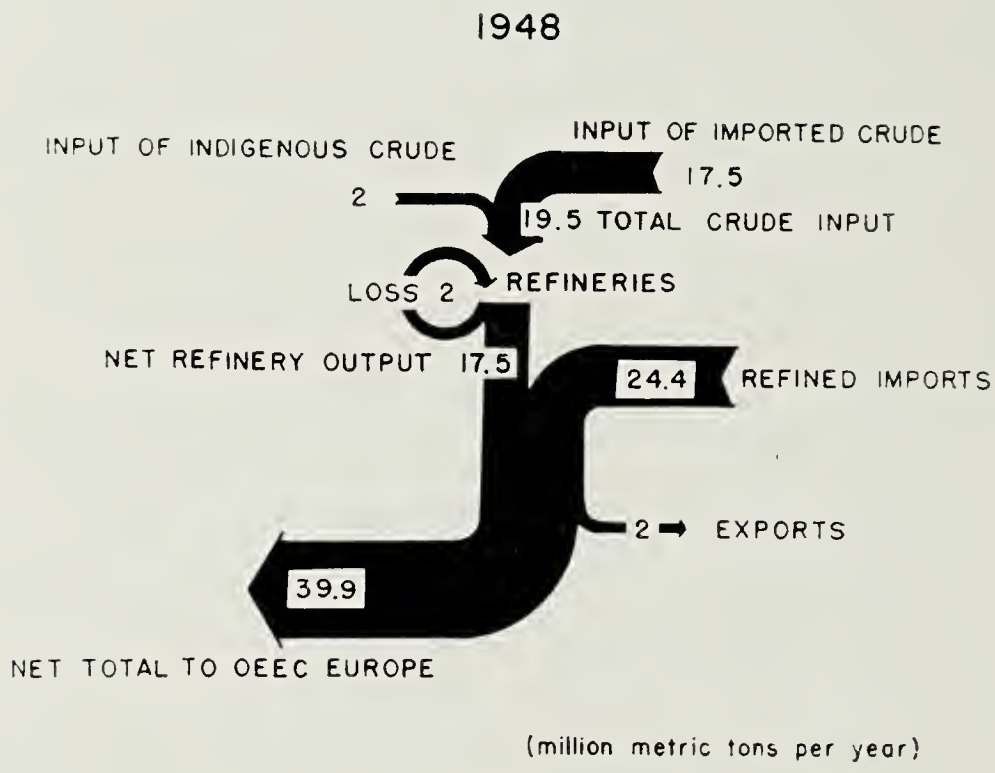

FIG. 3.—Movement of petroleum in Western Europe (1948).

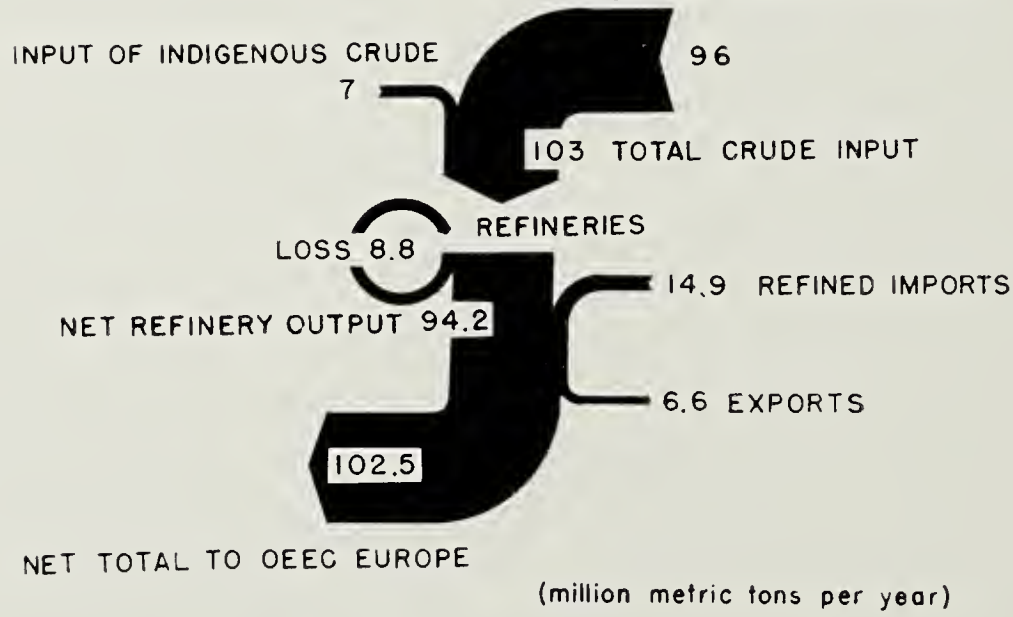

FIG. 4.—Movement of petroleum in Western Europe (1955).

18-20). The industry has progressed through the experimental stage and is now in the second stage of rapid growth. The next stage will be continued growth, but at a diminishing rate. Finally a stage of stability will be attained. This growth process, however, is dependent upon a continuing demand for petroleum products and the ability to market them at the lowest possible cost. The Middle East, with its abundant supply of labor and its natural resources, may develop refining industries and enter world competition for petroleum markets. Such an

occurrence would result in a second phase of reorganization in Western Europe because the market growth principle would be interrupted. If market area refineries are to continue to supply the bulk of the refined products to Western Europe, the present marketing system and its advantages must be maintained.

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KENYA, EAST AFRICA: AN ASPECT OF POPULATION GEOGRAPHY

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During and after the Second World War, the nations of the Western World showed an increasing awareness of underdeveloped areas as potential sources of agricultural and mineral production as well as possible sites for future migrations from Europe. One of the potential sites for European population is the British Colony and Protectorate of Kenya in Africa. The European population of Kenya increased from 528 in 1901 to 29,660 in 1948, the date of the latest census. Here, political, environmental, and economic factors have been favorable for the development of European settlement.

One of the principal factors aiding and encouraging the development of European settlement in Kenya has been government policy (Fig. 1). The first governmental encouragement for European immigration to Kenya was in 1904, when a representative of the Government of Kenya went to South Africa to advertise the potentialities of the highlands for European settlement. Other governmentally sponsored settlement schemes were inaugurated after both World Wars in an effort to encourage additional European settlement, particularly from Great Britain. The present government-sponsored, Soldier Settlement Scheme provides training, low interest loans from the Land Bank, and direct grants for the purchase of capital farming equipment, to prospective settlers. Additional aid to European agricultural settlement is provided by government-sponsored agricultural research, maize and wheat subsidies, and government-sponsored marketing schemes.

Perhaps the most significant political factor in the growth and distribution of European settlement in Kenya was the establishment of the boundaries of the White Highlands in 1939. No land can be excised within the White Highlands without the approval of the Highlands Board, which in effect means that only Europeans can own agricultural land therein. In 1948, there was a total of 7,945,038 acres reserved for European settlement. This also includes the areas of unalienated Crown Land reserved for future European settlement, notably in the southern portion of the Rift Valley and to the east and north of Nairobi. The former two areas are lower, warmer, and drier than the more densely settled rural portion of the highlands, while north of Nairobi, beyond Nanyuki, railroad facilities are lacking. Settlement is not possible on the steeper slopes and higher elevations (Mt. Kenya, Aberdare Range, Mau Escarpment, and upper slopes of Mt. Elgon) which, in 1939, were classified as Forest Reserve, where neither Euro-

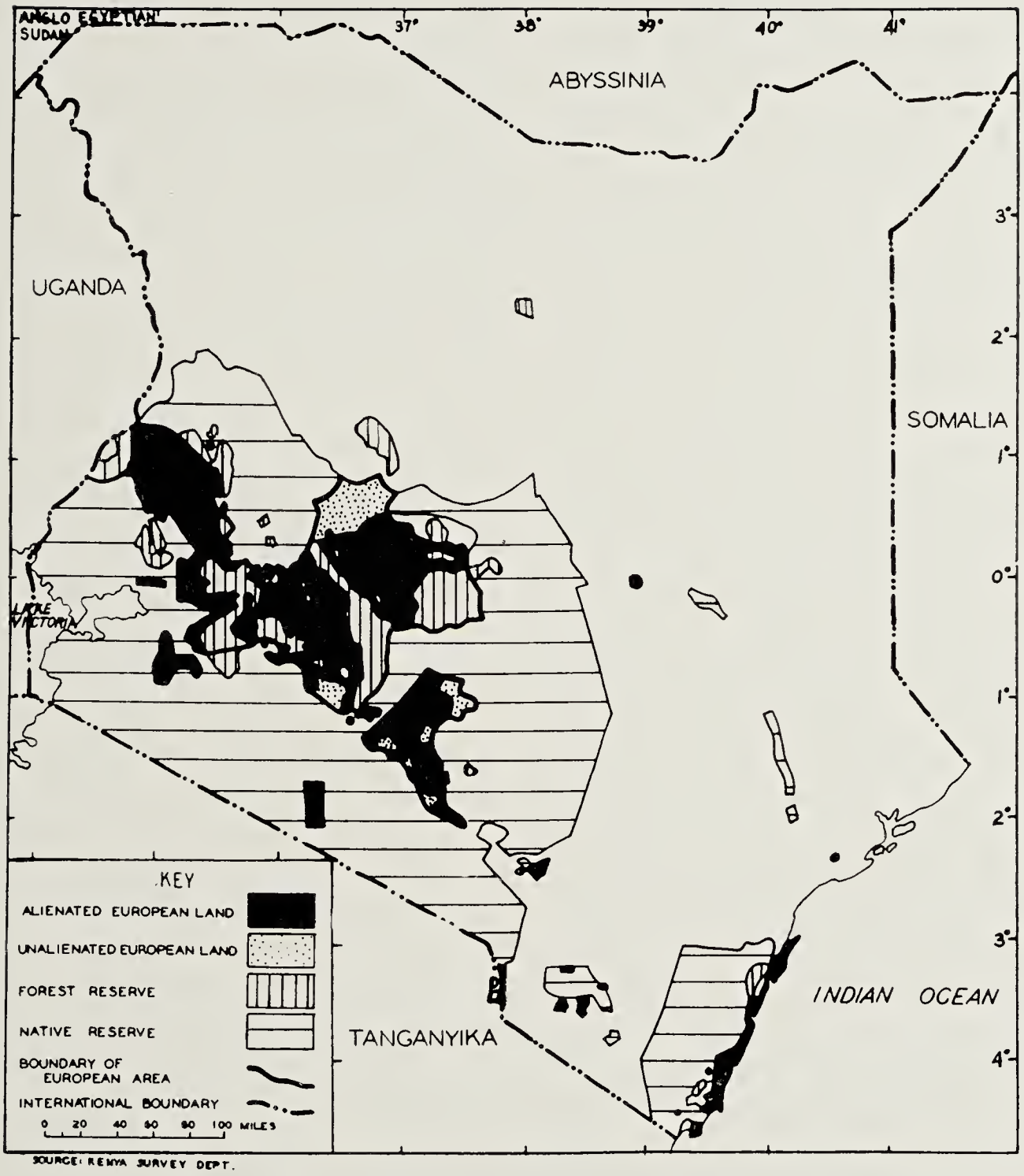

FIG. 1.—Classification of land in Kenya, 1947.

peans nor Africans can alienate land. The Native Reserves, wherein are found lower elevations, higher temperatures, less adequate rainfall, tsetse fly, and more limited transportation facilities, are also unavailable for European settlement due to governmental restrictions.

Six major European settlements can be differentiated where the size and nature of European settlement are reflections of a combination of political, environmental, and economic factors (Fig. 2). Throughout Kenya the majority of Europeans is situated in the southwestern portion of the territory with two notable exceptions, the ports of Mombasa on the Indian Ocean and Kisuma on Lake Victoria.

The most important European settlement in Kenya is in the southwest, in the White Highlands, which include the Rift Valley and the adjacent highlands between Mt. Kenya on the east and Mt. Elgon on the west. Such environmental factors as moderate temperatures, adequate rain-

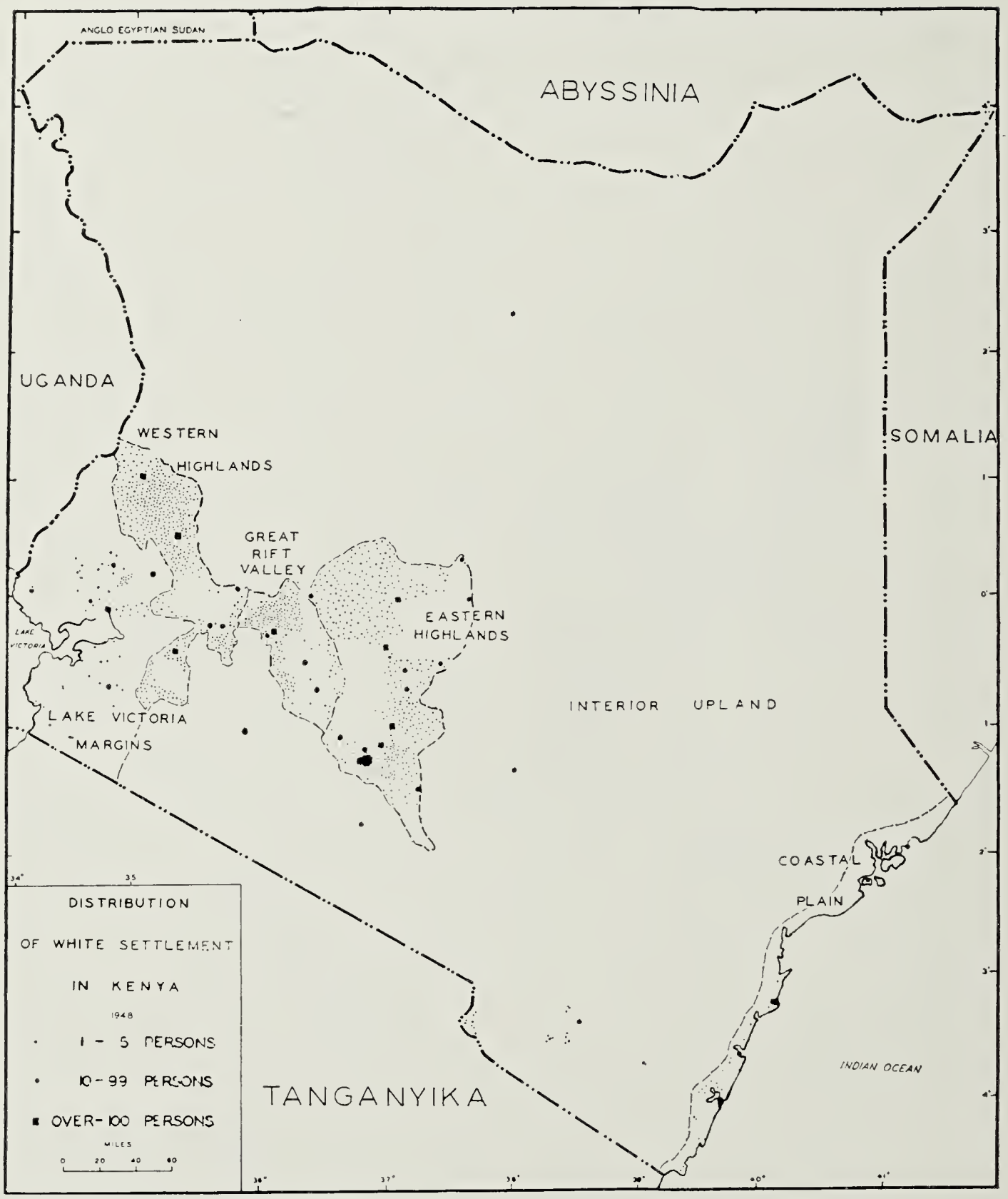

FIG. 2.—Distribution of white settlement in Kenya, 1948.

fall, relatively level local relief, and fertile soils, have been favorable for the development of white settement and 86.3% of the total European population is situated there. Three major European settlement regions have developed within the White Highlands; the two largest groups of Europeans are located in the Eastern Highlands and Western Highlands adjacent to the Rift Valley, while the smaller European group is situated in the Rift Valley itself.

The Eastern Highlands, where the largest European settlement in the White Highlands is situated, consists of a lava plateau located between the Aberdare Range, which is the eastern escarpment of the Rift Valley, and Mt. Kenya. Elevations

range upwards from 3,500 feet above sea level. The vegetation and climate, which vary locally with altitude and exposure, include: 1) Acacia tall-grass savanna in the warmer and drier sectors below the 5,000-foot contour; 2) the Temperate Rainforest in the cooler and moister sectors between 5,000 and 8,000 feet above sea level; and 3) above the 8,000-foot contour the vegetation includes bamboo, mountain meadow, and tundra. The best agricultural soils are in the relatively densely populated southern portion centering on Nairobi, 5,495 feet above sea level. Here the volcanic parent rock has weathered into a bright red friable loam over 15 feet in depth. There is a relatively evenly distributed annual rainfall between 40 and 50 inches, and annual temperatures range between 65° and 72° F. Nairobi, the capital and largest city in Kenya, is the principal administrative, commercial, and missionary center within the territory. To the north, south, and east of Nairobi, the rainfall is neither abundant nor prolonged, the principal soils are calcareous black clays, and the density of the European population is less. To the west, the steep slopes of the Aberdare Range have limited the development of European settlement.

The second principal concentration of European population in the White Highlands is found west of the Rift Valley in the Western Highlands where elevations range from 3,000 to 14,178 feet above sea level. The majority of Europeans is situated on the comparatively level Uasin Gishu Plateau between 6,000 and 8,000 feet, where the rainfall, temperatures, and soils are similar to those in the vicinity of Nairobi. South of the Uasin Gishu Plateau, the relief is more pronounced, and the European settlements are smaller and farther apart.

The smallest European settlement within the White Highlands is situated in the Rift Valley. The only significant concentration of Europeans is found in the more humid western portion of the Rift Valley near the base of the Mau Escarpment in an area of orographic rainfall. The steep escarpment of the Aberdare Range to the east rises abruptly above the relatively level surface and shields the eastern portion of the Rift Valley from the rain-bearing easterly winds. The Acacia tall-grass vegetation and non-calcareous plains soils reflect the drier conditions in most of the Rift Valley, in contrast to the more humid adjacent highland regions. A series of interior basins, the majority of which contain saline lakes, is an additional indication of the relatively subhumid conditions within most of the Rift Valley.

In 1948, 23.9% of the 13,979 gainfully employed Europeans in Kenya were engaged in agriculture and stock breeding, 20.6% in public service, 11.4% in wholesale and retail trade, and 11.0% in professional occupations. The majority of the European agriculturists are either permanent immigrants to Kenya or they are children or grandchildren of the early "pioneer" agriculturists. The other occupational groups are predominantly temporary settlers coming to Kenya under a limited contract. In contrast to the remainder of Kenya, the Euro-

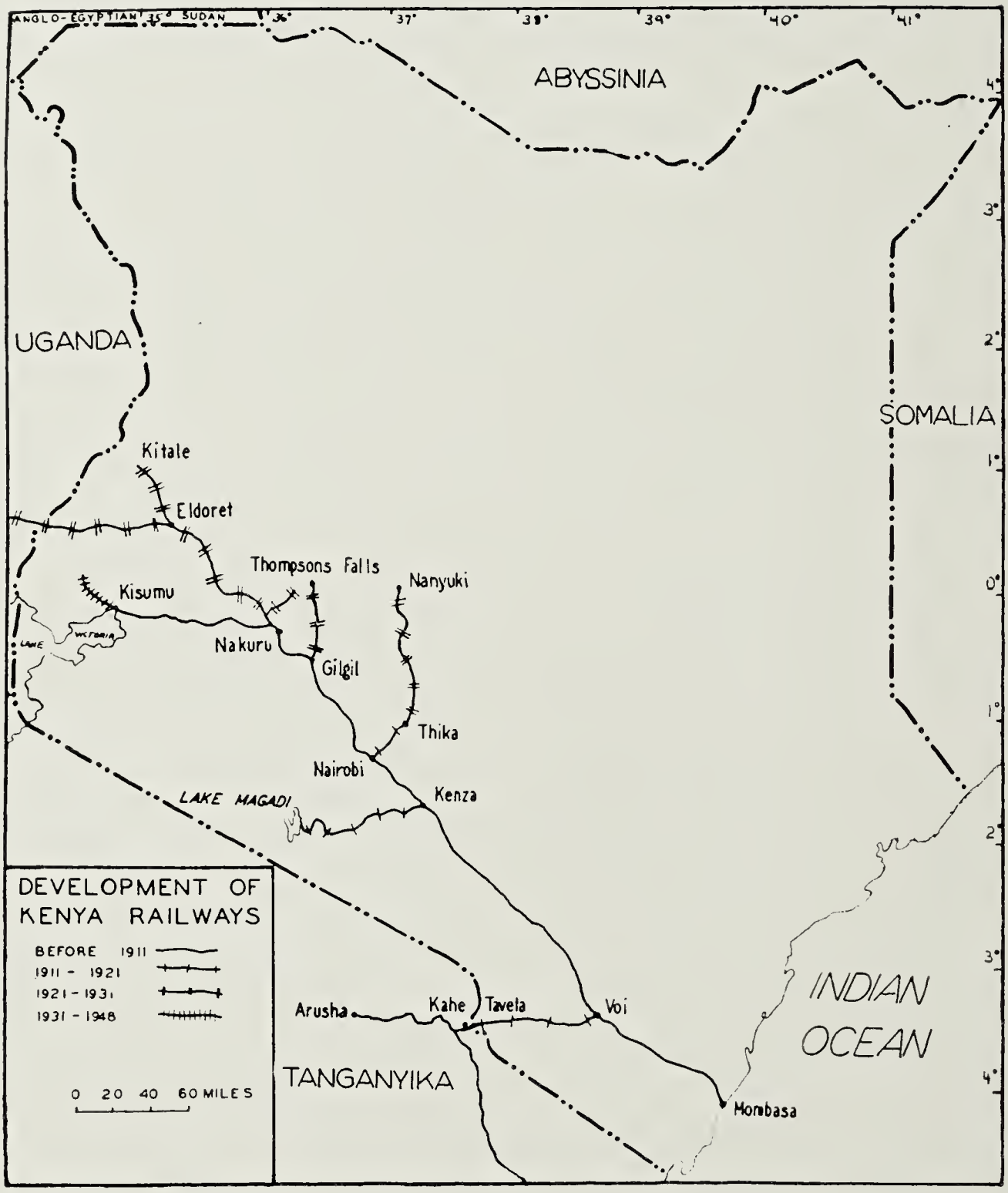

FIG. 3.—Development of Kenya railways.

pean population in the White Highlands is relatively permanent in nature, particularly that part engaged in agriculture and stock breeding. Among the European-grown agricultural crops, maize is the principal crop with a large domestic demand for livestock feed and human food. This crop is produced primarily in the humid portions of the White Highlands below 7,500 feet. Both livestock and wheat production have increased in the past 20 years due to government-sponsored research and disease control schemes. Coffee, pyrethrum, and tea production is confined primarily to the moister portions of the White Highlands, while sisal, which requires a drier environment, is raised in the lower portion of the White Highlands.

The development of permanent European settlement and economic activity in the White Highlands has been closely related to the presence of scheduled railway facilities (Fig.

3) which have decreased the isolation of the area and enabled the production of commodities which can be exported economically. In 1901, when the railway line was completed between the ports of Mombasa on the Indian Ocean and Kisuma on the shores of Lake Victoria, the majority of Europeans was situated in the vicinity of Mombasa. Shortly after the completion of the railway, the number of Europeans increased in the White Highlands, notably near Nairobi and Nakuru, which soon became the principal sites of European settlement in Kenya. Subsequent extensions of the railway in the White Highlands were followed by changes in the distribution as well as by increases in the size of the European settlement in the White Highlands. At present, all of the major urban concentrations are provided with scheduled transportation facilities which extend to adjacent territories as well as to the port of Mombasa.

To the east, in the Coastal Plain bordering the shores of the Indian Ocean, the environmental factors have been relatively unattractive for the development of a large or permanent European population (Fig. 2). The soils are predominantly loose sand; the temperatures are hot (above 68° F.) every month of the year due to the low elevations at this latitude; and the occurrence and amount of rainfall vary from high humidity in the southern portion to aridity in the north where continuous drought prevails for over three months of the year. The principal site of European population in this region is at the port of Mombasa (2,027 Europeans) which is one of the best ports on the east coast of Africa and the terminus of the Kenya and Uganda Railway. Within the port of Mombasa, European activity is predominantly commercial and administrative, whereas outside of Mombasa the comparatively small European population consists largely of plantation managers or public servants on limited contract. Sisal, the principal commercial crop produced here, involves huge capital investments, and its production is controlled primarily by large corporations rather than by individual producers.

In the Lake Victoria Margins in the western portion of the territory, the only important European settlements are at the port of Kisuma and the Kakamega gold fields. The days of the Kakamega gold rush by many European gold prospectors and miners stopped about 1935, and today the gold mining operations are controlled by large companies employing a limited number of Europeans on contract. The constantly hot temperature (above 68° F.), the high daily humidity due to the proximity of Lake Victoria, and the relatively infertile and easily leached, red-earth soils, formed on gneiss and granite, have not favored the development of white settlement. Relatively few Europeans have been attracted to the region, aside from those engaged in the mining and commercial activities related to the port of Kisuma.

The arid Interior Uplands is the largest (90% of Kenya) and least attractive region for the development of permanent white settlement. The majority of Europeans in this region are temporary settlers en-

gaged in either governmental or missionary service, aside from the relatively few Europeans temporarily employed as managers and technicians to direct mineral exploitation at the Lake Magadi Soda Mines. In the Interior Uplands the prevailing Acacia desert-grass savanna vegetation as well as the desert soils reflect the aridity of the region. Rainfall is sparse and unreliable, partly because of the distance from the Indian Ocean, and partly because the elevations, which range between 1,000 and 4,000 feet above sea level, are not high enough to modify temperatures and thereby lower evaporation sufficiently to permit effective rainfall. Moreover, the widespread distribution of the tsetse fly in this entire region has limited the development of European livestock production.

Thus, in the Coastal Plain, Lake Victoria Margin, and Interior Upland Regions, European settlement is small, scattered, and largely temporary in nature. None of these regions is likely to become the site of significant European settlement in the future. Unless new mineral reserves are discovered, or more effective methods of utilizing the existing water resources are developed, or the existing governmental policy concerning African interest is changed markedly, the European settlement of Kenya in the future will continue to follow the present patterns of distribution. The probable future increases in the size of the European population will result in denser settlement within the area reserved for Europeans, which is located primarily in the White Highlands.

A LAND-USE MAP FROM CENSUS DATA—PARANA, BRAZIL, AS AN EXAMPLE

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Introduction

Brazil is a large, important country with a rapidly growing population which has been extending the area devoted to crops. Furthermore, there has been a conscious effort to diversify farm output throughout Brazil, and evidence indicates changing land-use in the old, settled portions of the country. Field reconnaissance carried out by the writer in the summer of 1956 and a review of the literature indicate existing land-use maps of Brazil are out of date in many respects. Thus, a new land-use map is needed for a clearer understanding of the agricultural picture of Brazil.

The recently published, 1950-census of agriculture for Brazil offers specific data for making up-to-date land-use maps of the country. This paper explains the methods used in making a land-use map of Paraná state—a first step toward mapping the land-use of the country itself. Paraná was chosen as a test case for evaluating methods of transforming numerical data into map patterns that show land-use generalizations sufficiently simple to be comprehended for the whole of Brazil.

Paraná appears appropriate as a choice for a preliminary land-use map because within this state there is a variety of conditions broadly representative of large sections of Brazil. For example, geologic and landform features such as the diabase plateau, the great escarpment, and a strip of coastal plain are to be found. Also, the state straddles the frost line, a factor reflected in the variety of agricultural crops and natural vegetation existing there. Finally, the state has long-settled areas as well as sections of an expanding agricultural frontier, hence various stages of land occupance are to be found.

Kind of Census Data Available

The 1950 agricultural census of Brazil presents a variety of data by municipios (counties). The municipio information used in making the land-use maps included the following: 1) total area of each municipio reporting—the area where occupancy or ownership was sufficiently clear for responsible persons to complete and return census forms; 2) area in annual and perennial crops; 3) area in natural and planted pasture; 4) area in virgin forest and area planted to "useful" trees; and 5) uncultivated areas which include fallow lands, natural second-growth forest, and scrub forest. Other tables list the areas devoted to principal crops which for Paraná included 10 perennials (bananas, coffee, apples, etc.) and 15 annuals (cotton, rice, corn, etc.).

Determining Gross Land-use Patterns

Preliminary work involved adding together the area devoted to the two kinds of crops, pasture, and forest. The uncultivated land was added to the areas of forest. Calculations were then made to find the percentage of land occupied by crops, pasture, and forest in each municipio. Later the percentage of the cropland occupied by individual crops was found.

The census information cited above was analyzed in many ways and numerous patterns were mapped. The various criteria used were then tested in two ways. First, by attempting to correlate these mapped patterns with a variety of published materials such as maps of natural vegetation, geology, corn production, and cattle grazing. Second, the patterns were judged by personal observations made during automobile field trips in 1948 and 1956.

Thus, the following method of mapping the gross land-use patterns evolved. Municipios with less than 25% of their total area reported in any manner on census returns are considered "undeveloped." In municipios with less than 10% of the reported area in crops the land-use is classified as "pasture" or "forest" according to whether pasture or forest leads in area occupied. Municipios with 10 through 19% of their reported areas in crops are classified as "crop-pasture" or "crop-forest" according to whether pasture or forest occupies the greater area. In those municipios where crops occupy 20% or more of the total area reported, the land-use is classified as "cropland" (Fig. 1).

Fig. 1.—Gross land-use: 1) cropland; 2) crop-forest; 3) crop-pasture; 4) pasture; 5) forest; 6) undeveloped.

Gross Land-use and Other Patterns Compared

Maack's (1950) map of natural vegetation corresponds with the gross land-use patterns in many ways. The tropical rain forest area associated with the sea-facing escarpment nearly coincides with one of the two areas mapped as undeveloped—that is, areas where census returns were made for less than 25% of the land area. Naturally this near coincidence is more than a relationship between vegetation and land-use. The sparce occupancy is related, however, to a number of conditions observable on Maack's map—namely steep slopes, poorly drained areas near the foot of the escarpment, and sandy regions along the coast. This is an area long exposed to settlement but one where the natural environment has not favored dense occupancy by man. The other region of undeveloped land is very large and is on or beyond the frontier of settlement. It is not clear whether land quality as reflected in natural vegetation has

restricted settlement here, but this is implied by the close similarity of the boundaries of the undeveloped area and a vast area of tropical and subtropical forest distinguished by Maack. By comparing the land-use map with Maack's (1953) geology map of Paraná one can see that much of the northern half of the undeveloped area is made up of Jurassic sandstone (Caiuá), whereas most of the important cropland area in northeastern Paraná is shown as diabase.

The validity of the gross land-use map based on census returns is further attested to by comparing the map's pasture areas with the *campos limpos* or grass lands sections of Maack's vegetation map. If space permitted other correlations could be pointed out.

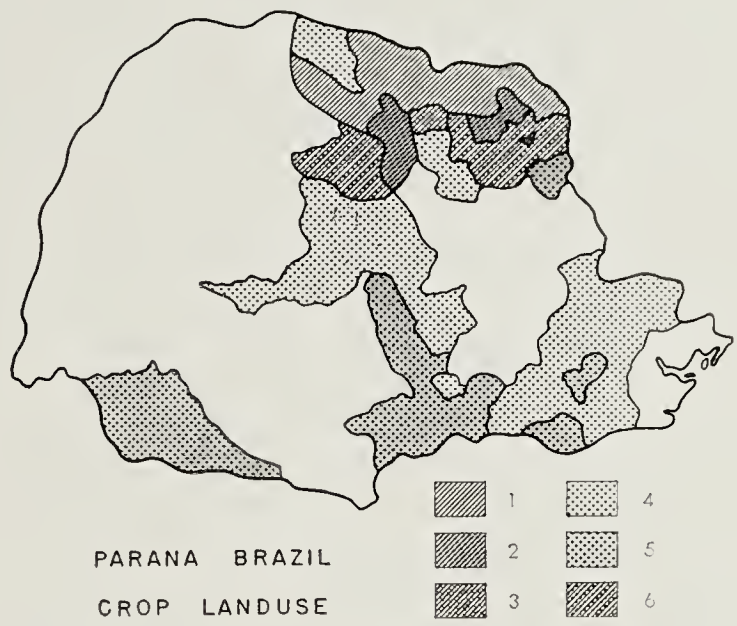

Fig. 2.—Crop land-use: 1) coffee; 2) coffee-grain; 3) coffee-cotton; 4) corn; 5) corn-grain; 6) corn-coffee.

Determining Crop Land-use Patterns

For simplification the pasture, forest, and undeveloped areas are left blank on the crop land-use map (Fig. 2). The three areas indicated as cropland, crop-forest, and crop-pasture on the gross land-use map are refined on the second map where dominant crops and crop combinations are shown.

First, only crops occupying 10% or more of the cropland were considered. Weaver (1956:564) pointed out that "If the percentage of total harvested cropland for a given crop in a township or county is 10 or 11, it may be presumed that the crop will be found on about two-thirds of the farms" in the Middle West of the United States.

For simplification only the two highest-ranking crops were considered and second-ranking crops were grouped as to type. Thus corn, rice, wheat, and rye are classified as "grain" when any of these four are secondary in area occupied by crops.

Results of the Method

The result is a simple map (Fig. 2) requiring only six patterns to show the dominant crops and crop combinations of the state. In 33 municipios a single crop dominates —16 are coffee municipios and corn is the dominant crop in 17 others. In the remainder of the crop areas two or more crops occupy at least 10% of the cropland.

The method here employed in making a land-use map of Paraná is meant to serve as a guide for developing a one-color land-use map of the whole of Brazil. To be most useful, such a map should be sufficiently generalized to convey a clear picture of crop patterns to the map user. Weaver's (1954) map of the Middle West presents 31 crop com-

binations that would make comprehension of distribution patterns next to impossible on a one-color map. Weaver's complicated map results from his inclusion of all crops produced. Paraná's 90 municipios account for less than 5% of Brazil's municipios and to make crop combinations of all crops occupying only 5% of the cropland would result in 17 combinations. Considering only those crops accounting for 10% or more of the cropland gives us 11 combinations, if the second crop is not grouped under a common heading as described above. With this number of patterns for Paraná alone, a map of Brazil would be too complex for easy comprehension.

Summary

The Brazilian state of Paraná has been used to illustrate a method of making an up-to-date land-use map for Brazil. A primary objective has been a map on which the patterns representing crops and crop-combinations are few enough in number to result in a map that is simple to comprehend but accurate in its portrayal of the agricultural land-use of Brazil. The map resulting from the system described in this paper appears to meet this objective.

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LARGE SCALE COMMERCIAL BEEF CATTLE FEEDING IN NORTHERN ILLINOIS

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Introduction

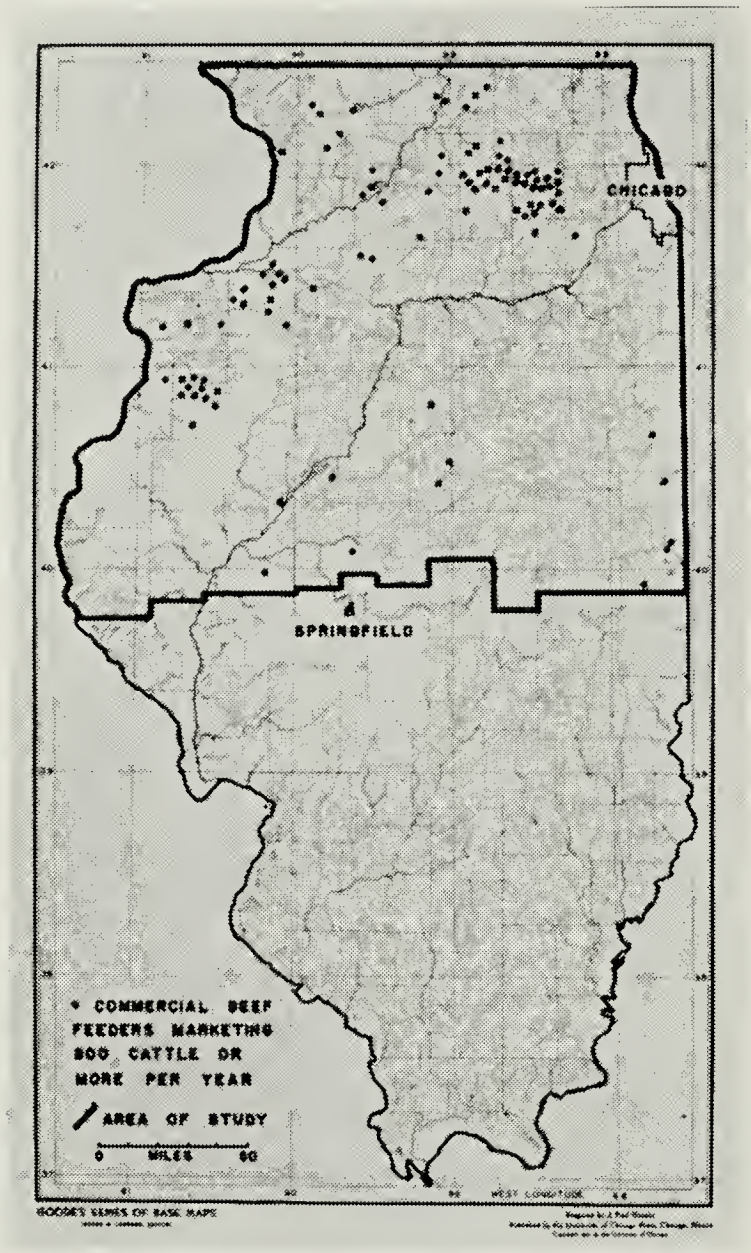
For the past three decades the average size of farms in the United States has been increasing. Part of the increase is accounted for by the increases in the size of family-type farms; but there have also developed some very large-scale agricultural operations either individually or corporately owned. These extremely large, industrial-type operations are of various kinds: large-scale livestock ranches, vegetable farms, orchards, broiler chicken factories, wheat farms, and others. Some agricultural experts anticipate that future agricultural production in the United States will come largely from these big, efficiently managed enterprises. It is clearly of the greatest importance to United States agricultural policy to have an accurate view of the relative effectiveness of large-scale farms and family-size farms in American agricultural production.

One kind of factory-type agricultural operation is the large beef-cattle feeder. This investigation is concerned with the numbers and distribution of large-scale, beef-cattle feeders in northern Illinois, and with a preliminary description of the mode of operations of a few of these feeding units.

If we classify all commercial beef feeders in Illinois on the basis of size of operations, we discover that they are arranged in a continuum from the very largest to the tiniest operations. Therefore, any figure selected to define the minimum size of operations of a large-scale feeder must be arbitrary. For this study a large-scale feeder was defined as any operator who fed and marketed more than 800 head of beef cattle per year. This is a large number, and unquestionably some corporate-type operations not quite of this size were excluded by our definition. The size defined has the advantage, however, of being sufficiently large that the family-type farms, even large ones, are excluded.

Distribution in Illinois

The areal distribution of enterprises feeding and marketing more than 800 head of cattle per year is shown on the accompanying map. One of the most striking aspects of the map is the extremely uneven distribution of such beef-feeding enterprises. Less than half of all northern Illinois counties (23 out of 50) have even one feeder of this scale of operations. According to information furnished by the county agents in their respective counties, there are in the counties north of the south boundary of Adams, Logan, and Champaign counties 102 cattle-feed-



ing operations which market over 800 head of stock each year. Sixty-two percent of these enterprises are located in just 4 of the 50 counties. They are concentrated in two nodes. One node is in DeKalb and Kane counties just west of the Chicago metropolitan area where more than 40 of these enterprises are located. The other concentration is in Warren and Henry counties in the livestock feeding area just east of the Mississippi River. The map also indicates that the rest are widely scattered. Only one other county has as many as five such enterprises—Lee County located between DeKalb and Henry counties. With the exception of DeKalb and Kane counties, it is clear that most of the large feeding operations are located in the northwestern quarter of the state.

Having established the distribution and numbers of large feeders in northern Illinois, the next step was to obtain some preliminary ideas about the characteristics of these operations. To do this we have undertaken a more intensive study of the large feeder operations in DeKalb County.

Ownership and Organization Characteristics

The large feeding enterprises of DeKalb County show the greatest diversity in both organization and ownership. The simplest pattern found in the county is that of an individual farmer who owns 560 contiguous acres of land, which are operated with a minimum of hired help. He feeds for a 90-day period a total of about 1,000 head of beef cattle each year and purchases more than half of the necessary feed.

A slightly more complex arrangement is that of an elderly farmer who owns two farms about ten miles apart. Both of the farms are actively managed by his son who operates one of the farms, with a hired man operating the other. This man is known as a "long feeder"; *i.e.*, his stock is fed for a nine- or ten-month period. He is one of the few operators who feeds Angus cattle exclusively, feeding and marketing about 1,500 head annually.

A still higher level of complexity is represented by a feeder who owns and operates one large farm of 400 acres, but who owns two other farms which he rents on a tenant-share basis. About 1,000 head are fed on his own farm, for which he can raise

less than half the feed necessary. The rest of the feed is purchased. Smaller numbers of cattle are raised on an equal-share basis on the other two farms.

The next order of complexity of organization is exemplified by four contiguous farms owned by one man. The owner is a man of numerous business interests. He is a cattle dealer, purchasing through commission buyers on the western range and selling the stock to small feeders throughout the county. Cattle are also fed on his four farms. The number of cattle and the length of time they are fed vary widely, being largely dependent on the relationship between prices of feed and livestock. Cattle dealing occupies only part of this man's time, the rest of which is spent as a member of the Board of Trade in Chicago.

The next complex is an individually owned group of seven farms with a son working the home farm. In this operation the owner oversees all seven units. Cattle feeding is carried out on the home farm which markets 1,000 head annually.

A similar, but even larger, operation is represented by a group of 18 farms throughout DeKalb county owned and managed by one man. These farms average 200 acres each and are worked by tenants who raise about two-thirds of the feed for the cattle-feeding operations. The number of cattle fed varies from 30 to 225 head on each of the 18 farms. Combined operations of all farms market over 3,000 head annually.

Corporate cattle feeding operations in DeKalb County are both larger and smaller than the individually managed properties. Some of the corporate feeding operations are merely ancillary to the principal business of the corporation. A canning corporation feeds cattle as a method of utilizing hired farm help during the slack winter months. All of this corporation's farms are leased, and help is hired for the raising and harvesting of peas, corn, lima beans, squash, and pumpkins. When the harvest is completed cattle are purchased by a company buyer. The cattle are fed through the winter months, utilizing pea and corn silage from the canning process as part of the feed and thereby reducing grain costs and disposing of a canning by-product. The average farm, worked by one man, feeds 110 cattle. These farms, averaging 160 acres each, are located on outlying areas near the canning-plant location. They are located as contiguous as possible to each other and to the canning-plant district. Before the spring planting season arrives, the cattle are marketed.

A hybrid seed-corn company provides another example of beef feeding as an operation subordinate to the primary business. In raising seed corn much more corn is grown than can be sold as seed. Only enough seed is treated to satisfy demand, and the remainder is stored for cattle and hog-feeding purposes. Eight-hundred calves are divided equally between the four farms forming the company's farming unit. Calves are purchased and fed on the long-term plan, a less speculative plan for beef feeding.

While feeders have differences in organization, they do have certain common characteristics. Cattle for their farms are purchased on the

western range from Montana to Texas and New Mexico. Transportation of these cattle is entirely by rail.

About one-fourth of the total number of cattle is purchased at weights of 900 to 1,000 pounds and fed to grade "prime" at 1,200 to 1,300 pounds. Half of the total number of cattle is sold at grade "choice," and a fourth of them is marketed at grade "good." No large-scale feeders feed cattle for the commercial or utility grades.

Herefords constitute about 80% of the cattle fed. A feeder may purchase a few white-faced Angus, and others to feed with Herefords. Aberdeen Angus were fed only in two cases.

Close to 95% of the finished beeves are marketed at the Chicago Stockyards. The majority of the cattle are shipped to this market by truck. All but one feeder interviewed shipped by hired trucking concerns; this one feeder owns and operates his own truck. The largest volume of hauling is done on the weekend for the Monday market and much less on Tuesday for the Wednesday market. An average load per feeder is 18 to 25 head marketed once a month. Long-term and especially short-term feeders market cattle at frequent intervals, depending on the market and when the cattle are ready.

GEOLOGY

USES AND LIMITATIONS OF ELECTRICAL PROSPECTING FOR WATER SUPPLIES

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One of the many methods employed by the Illinois State Geological Survey in the search for groundwater supplies is the electrical earth-resistivity survey. It is used to locate water-bearing sand and gravel within glacial drift on the uplands and within alluvium in valley flats and lowlands. This program has been in continuous operation since Dr. M. King Hubbert's interest in it in the summer of 1932. Since that time nearly 500 separate surveys have been run, ranging in size from 10-station, 1-acre surveys for farm water supplies to 1000-station surveys on 100 square miles for municipal supplies. The surveys cover practically every physical environment found in Illinois (Fig.1).

Figure 2 shows diagrammatically the theory of the earth-resistivity test and the Wenner electrode configuration used by most investigators. The instruments used by the Illinois Geological Survey resemble closely the commutated direct-current circuits developed by O. H. Gish and W. J. Rooney of the Carnegie Institute of Research, using standard electrode spread. In some of our equipment we have recently substituted the synchronous vibrator for the hand-driven commutator. This provides a somewhat smoother operation but no noticeable increase in accuracy. Our newest instrument is small, hand commutated, and easily portable. Continuing improvement of field equipment and technique has led to many minor changes in instrumentation, but the operating theory remains the same.

Experience has shown that many of the materials making up the earth's crust can be identified, at least in some degree, by their reaction to the flow of a current of electricity. In this action, which is electrolytic in nature, the moisture of the ground, together with the dissolved impurities, gives to the several materials characteristic resistances, or resistivities, to a flow of current. These characteristics, when recognized, may be used for locating and, to some degree, identifying subsurface formations.

Ordinary moist soils containing moderate amounts of clay or silt with some more or less active electrolytic agent usually have a comparatively low resistance, but sand and gravel, dry loose soil, and solid rock usually have relatively high resistance. These classifications are far too general to be of use, but if we can make initial calibration near a test-hole or well or outcrop where the lithology is known, the resistivi-

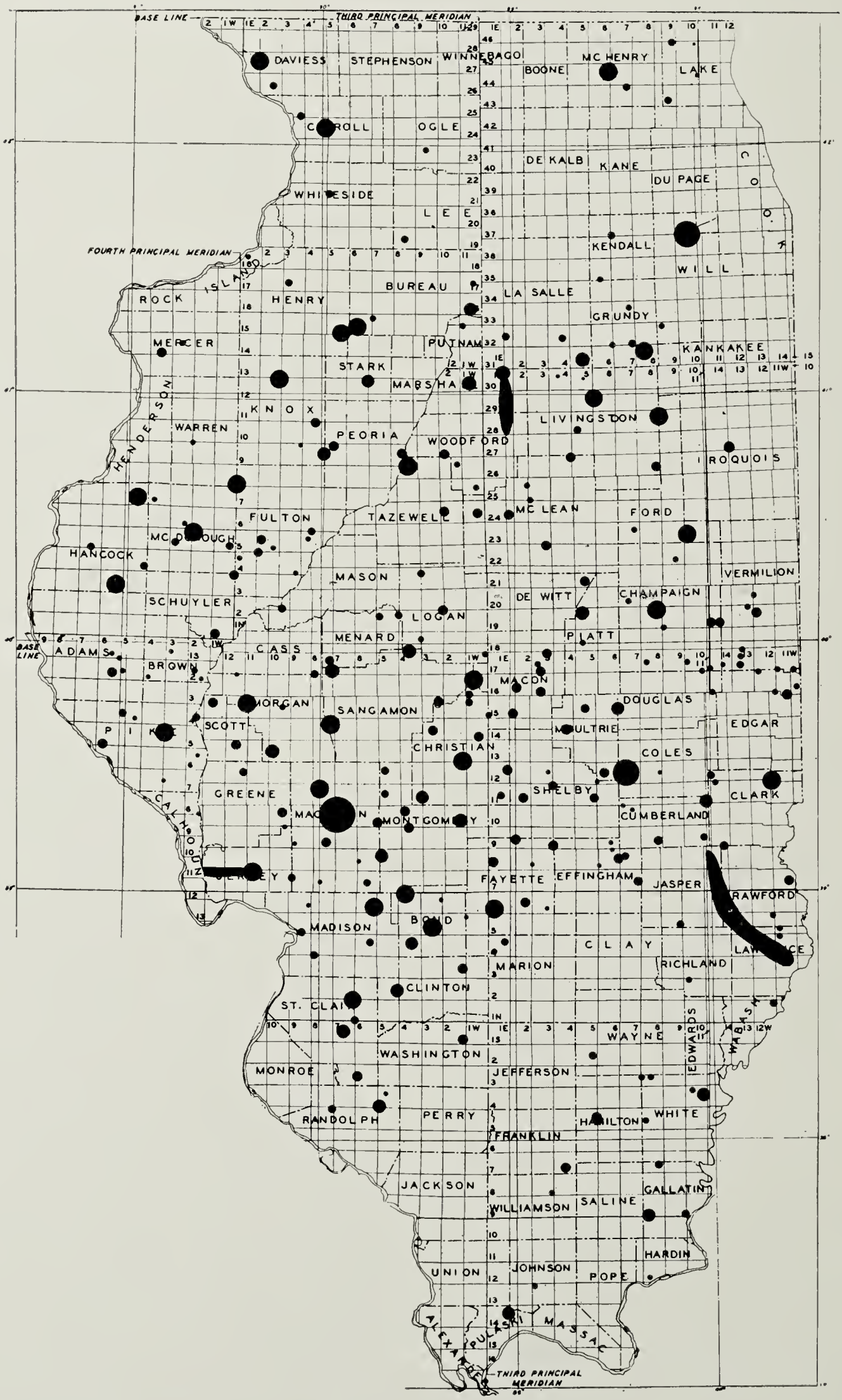

FIG. 1.—Distribution of earth-resistivity surveys, 1932-1956.

ties can be made meaningful, and a reasonably accurate analysis can be made as to the type and position of the underlying material.

Electrical prospecting for water-bearing deposits of sand and gravel is necessarily limited to the areas where such deposits could be expected to occur. In areas where the bedrock is at the surface, the search for these deposits is confined to creek flats and stream beds, both recent and ancient. In areas where glacial drift has been deposited, additional water-bearing lenses and beds of sand and gravel can and do occur anywhere throughout its entire thickness. In one area the local water supply is derived from a near-surface freshwater sandstone which has been found to be mappable by electrical methods. With this exception, electrical exploration for water-bearing beds has been confined to the unconsolidated material lying above bedrock.

Resistivity work in Illinois falls into five resistivity provinces (Fig. 3). Province 1 includes about 25,000 square miles and lies in an east-west belt across the state. It is within this area that electrical prospecting is most effective, as suggested by the number of surveys indicated on Figure 1. The glacial drift ranges from 0 to 400 feet in thickness but averages about 100 feet. The drift is chiefly underlain by rocks of the McLeansboro formation of Pennsylvanian age. These rocks are mostly low-resistivity shales with generally thin beds of limestone and sandstone which do not appear to raise the resistivities an appreciable amount. The glacial drift, which is chiefly clay and consequently has low resistivity, contrasts sharply with the high-resistivity sand and gravel or bedrock. The water-bearing zones in these bedrock layers are usually poor water-producers, and the water is considerably less desirable both in quantity and quality than water in the drift.

Province 2 comprises an area of about the northern one-fourth of the state where glacial drift, that is thin in the west and thick in the east, lies over fresh-water-bearing sandstones and limestone. Commercial quantities of water can usually be obtained from the bedrock formations without considering the glacial drift or its sand and gravel content. At many places, however, excellent water supplies are developed from the sand and gravel within the drift or in the flats of streams. Electrical prospecting is effective though it is used but little in this province.

Provinces 3 and 4 are areas where bedrock crops out at the surface, and electrical prospecting for water-bearing sand and gravel is confined to the beds of rivers and streams, both present and ancient. Away from stream beds in these areas the production of groundwater for public and private use depends, at least in northwestern Illinois, on the well encountering crevices in limestones or freshwater-bearing sandstones. In the southern part of the state the only potable water from the bedrock occurs in sandstones and limestones that are very near the surface in an area of outcrop. Undesirable qualities of water almost invariably appear to increase with depth.

In the stream valleys, local erosion has not, with the exception of the Cache River bottom, resulted in

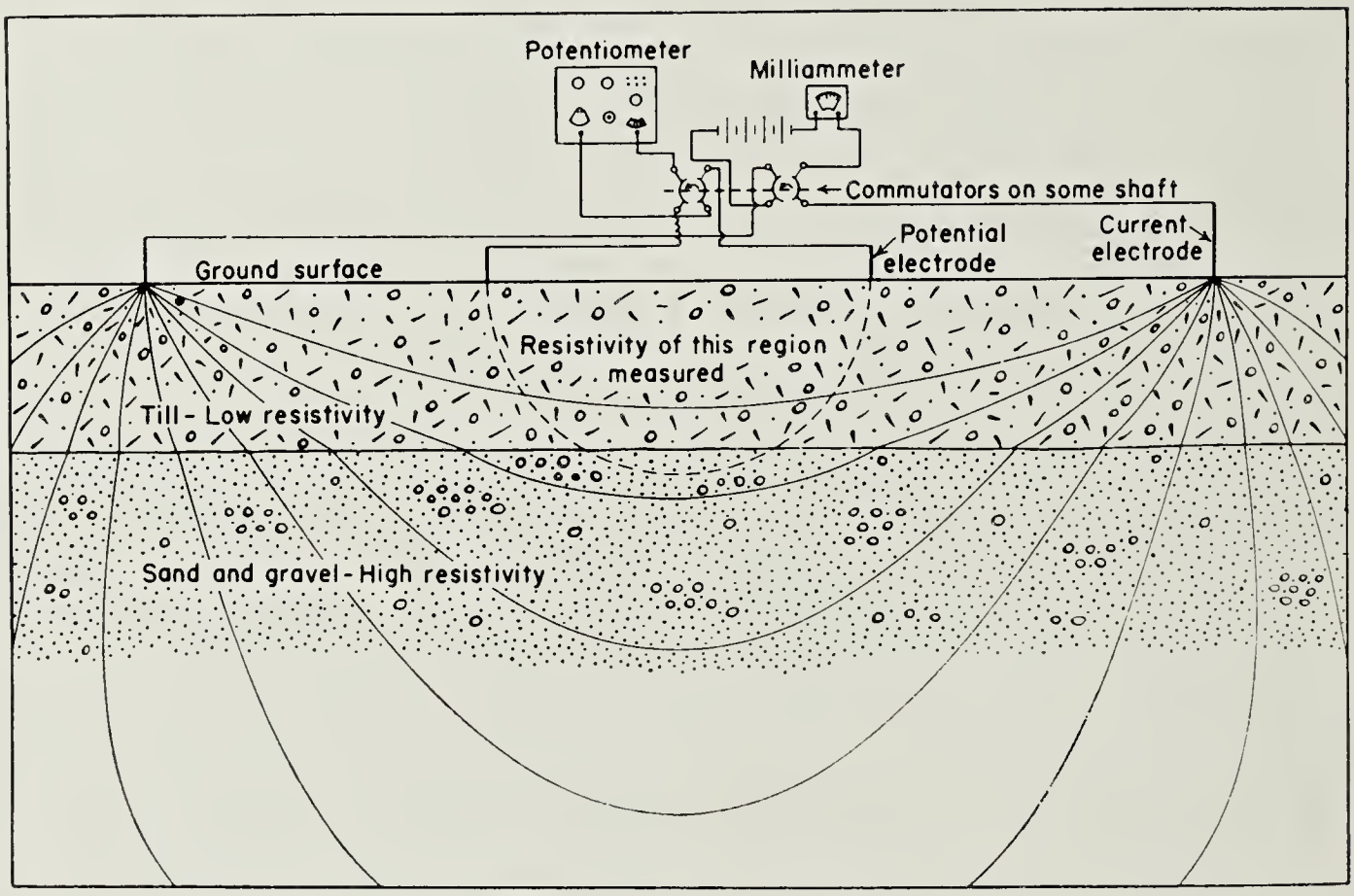

FIG. 2.—Diagram showing resistivity instrumentation and electrode separation.

enough alluvial fill to furnish commerical supplies of water. Electrical prospecting is successful in these provinces where the alluvial fill is sufficiently thick.

Province 5 is the area radiating out from East St. Louis where glacial ponding from the west caused all the streams to deposit their loads of silt along with normal amounts of sand and gravel. This silting extended up practically all the streams emptying into the area and in fact covered most of the low-lying portions of the upland. We believe this silt, or the clay suite with it, has a masking effect over known deposits of sand and gravel, preventing in some manner their detection by electrical methods. The hilltops and hillsides which remain effective sites for electrical exploration are rarely useful in the study of potential groundwater supplies.

In the study of electrical prospecting a simple guiding rule is as follows: the larger the volume of water needed, the larger the water-bearing deposit must be and therefore the easier it is to detect. The nearer the surface the deposit lies, the simpler is its detection.

The electrical earth-resistivity method of prospecting in Illinois is used most effectively where a large volume of water is needed, where geologic factors are favorable, and where the radius of permissible prospecting is fairly large, say within one to five miles of the point of use. For instance, a village whose minimum needs are 100 gallons per minute must have an aquifer 10 to 20 feet in thickness. Such a thickness is usually detectable within 100 feet of the surface. Test-hole sites are then chosen and where tested are usually favorable, thereby eliminating the drilling of many test-holes on a random basis. This work reduces the

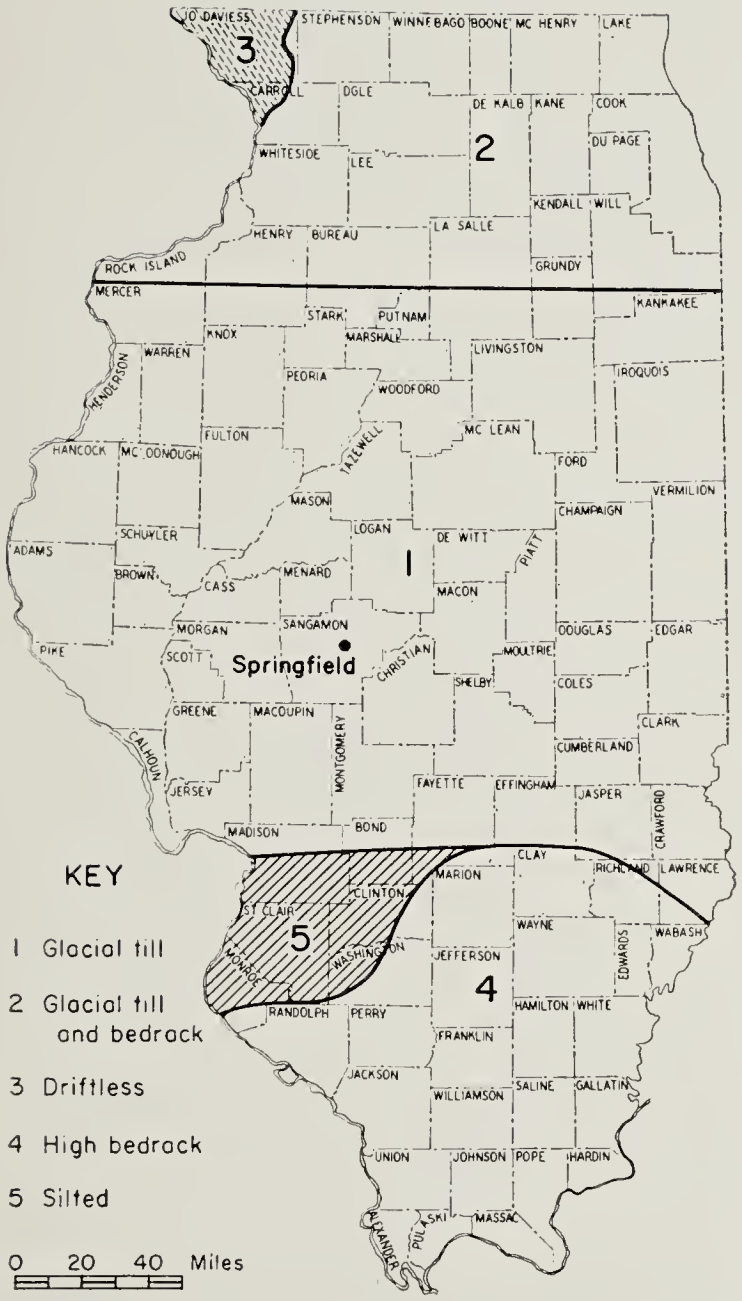

FIG. 3.—Generalized earth-resistivity provinces in Illinois.

area of consideration for test-drilling by about 95%.

The method is least effective on small-volume supplies, such as for individual dwellings or farms, where the area of prospecting is severely curtailed for economic or political reasons, as for instance, the perimeter of the village park or a farm barnyard, usually already drilled many times to no avail. No amount of prospecting of any kind will turn up a thick bed of water-bearing sand in the midst of several sandless, dry test-holes, although this is frequently expected. A residential or farm supply that needs only five or six gallons of water per minute could be supplied from two or more feet of gravel at any depth, yet two feet of clean gravel could not be detected electrically if it were only ten feet from the surface. It is also true that, if a sand 20 feet thick underlies a house or barnyard, the chances are that it has already been found. A very frequent problem is that in which sand has been encountered but the driller was unable to construct a sand-free well. The right solution here is proper well construction, not further exploration for more sand.

In a year of normal rainfall the Illinois State Geological Survey conducts 40 to 50 earth-resistivity surveys, about one third of them for municipalities; in a drouth year there may be as many as 70, about one fourth for municipalities. Many of these surveys in the past discovered new well fields and many more are seeking extensions of old supplies.

The high level of discoveries, nine of ten for municipal and commercial supplies, is commendable, especially because other methods have frequently failed to find a water supply. There has been an increasing tendency on the part of consulting engineers to call for an electrical earth resistivity survey and a study of ground-water possiblities before final evaluation is made of the estimated cost of municipal and commerical water systems.

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ELECTRIC-LOG CROSS-SECTIONS OF THE SILURIAN-DEVONIAN FORMATIONS OF A PART OF CENTRAL ILLINOIS

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Regional Setting

The area discussed is in the northwestern portion of the western shelf area (Fig. 1) of the Illinois basin (formerly called the Eastern Interior Basin), a large, spoon-shaped, structural basin in central and southern Illinois, southwestern Indiana, and northwestern Kentucky. The basin is surrounded by three major positive areas—the Wisconsin arch on the north, the Cincinnati arch on the east, and the Ozark dome on the southwest.

The three cross-sections presented here are part of a study being made preparatory to a revision of the subsurface structure map (Bell, 1943) of the base of the Kinderhook-New Albany shale in the southern two-thirds of Illinois. The base of the New Albany shale has been used as the datum plane for the cross-sections, and the sea-level and minus-2500-foot contours on this horizon are shown on the index map (Fig. 1).

The area represented on the three cross-sections is on the western shelf area northwest of the deep part of the basin. Cross-sections A-B-C (Fig. 2) and D-E (Fig. 3) run south to north, almost parallel to the strike of the shelf, and the F-G section (Fig. 3) runs west to east at approximately right angles to the strike.

In this area the base of the New Albany shale dips eastward into the basin. Cross-section A-B-C, extending from sec. 1, T. 18 N., R. 1 W., Logan County, to sec. 21, T. 6 N., R. 2 W., Bond County, has an average southward dip of 9 feet per mile for the entire distance of nearly 75 miles. Elevations range from 1040 to 1721 feet below sea-level. Along section F-G the dip eastward averages about 26 feet per mile. This cross-section runs from sec. 16, T. 13 N., R. 8 W., Morgan County, to sec. 9, T. 13 N., R. 1 E., Christian County, and the elevation of the base of the shale ranges from 277 feet below sea-level at the western point to 1665 feet below sea-level in the eastern test, a distance of about 50 miles.

Stratigraphy and Lithology

Rock formations present in this part of Illinois, from late Ordovician to early Mississippian time, are shown in Figure 4.

The Maquoketa shale, the uppermost Ordovician formation, is predominantly grayish green, with some relatively thin olive-gray limestone and dolomite beds in the middle portion of the shale. It is uniformly about 180 to 200 feet thick in the area.

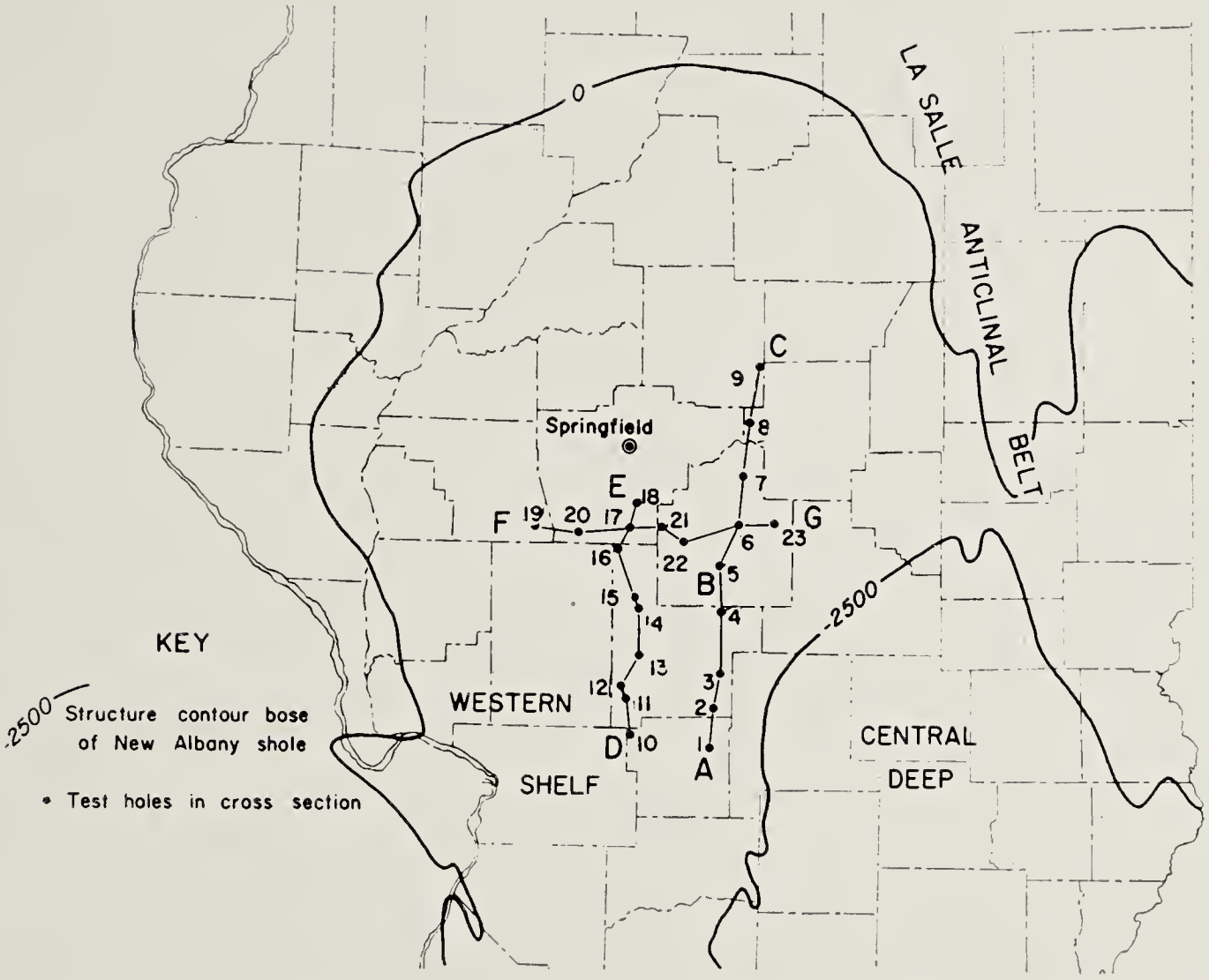

Fig. 1.—Map showing location of stratigraphic cross-sections.

The Alexandrian series, of Lower Silurian age, is about 50 feet thick in this area. The Edgewood formation at the base is commonly a thin, brownish gray, very fine-grained, silty dolomite. The overlying Kankakee formation, about 45 feet thick, is a white to buff, very fine-grained cherty limestone, often containing glauconite.

In northern Illinois the Niagaran series, of Middle Silurian age, consists of four different formations, which in ascending order are the Joliet, Waukesha, Racine, and Port Byron. Southern Illinois correlatives are the St. Clair and Moccasin Springs formations. Both sets of names have been used to designate the formations in the area studied.

A sample study of the Huber No. 1 Kunz test in sec. 11, T. 6 N., R. 5 W., Bond County, made by E. A. Atherton of the Survey staff, shows the Niagaran series to be about 450 feet thick at that place. The lower 175 feet are a red and greenish gray, very finely crystalline limestone and dolomite sequence, argillaceous in the upper 80 to 100 feet and pure limestone with red grains and pink crinoid plates in the lower part. This is the "red" Bainbridge group, composed of the argillaceous Moccasin Springs limestone resting on the purer St. Clair limestone.

Above the red section, another 135 feet of rock is similar except that the limestones contain more dolomite and chert and are not red.

The upper 135 feet consist of grayish or grayish green to brown dolo-

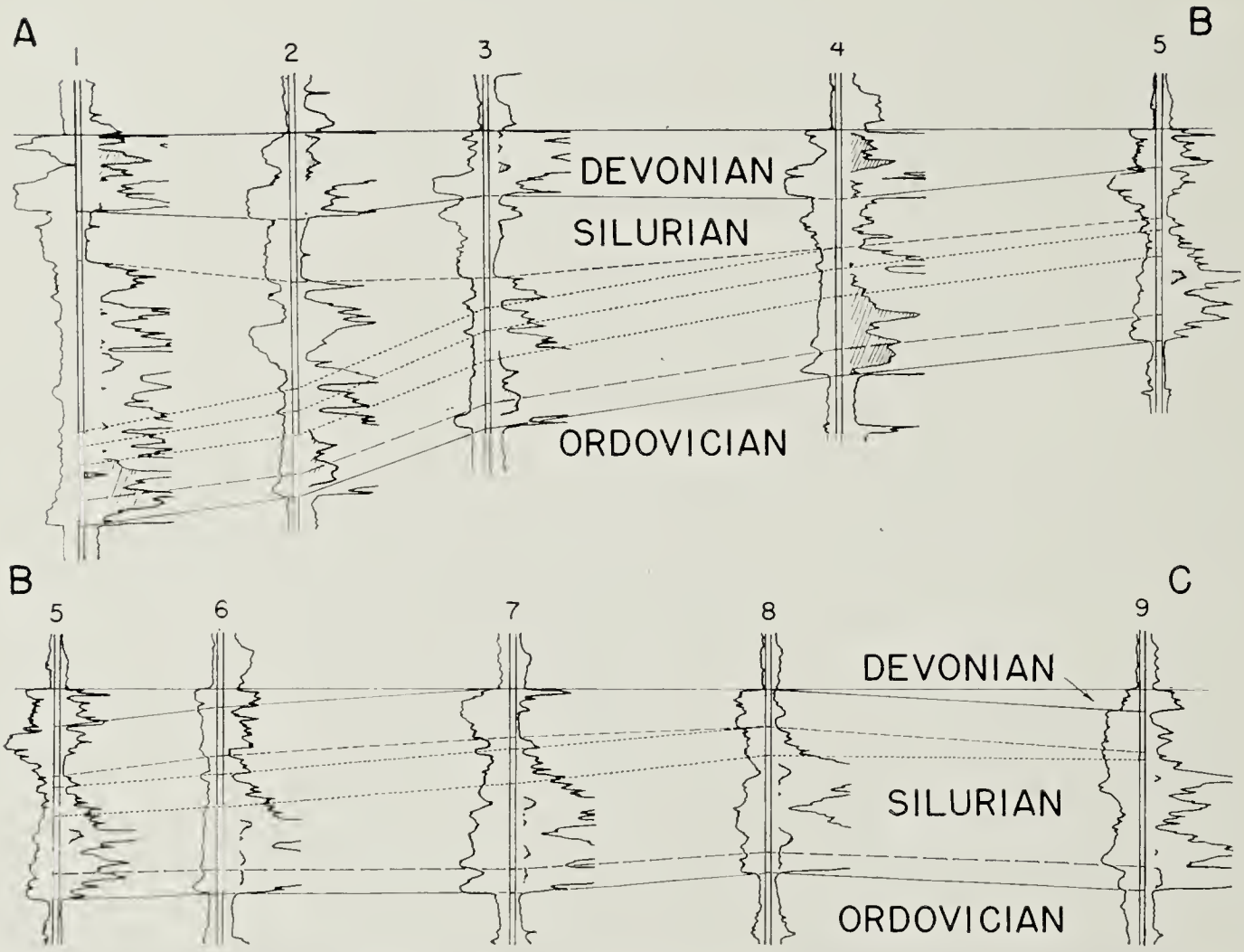

FIG. 2.—Stratigraphic cross-section A-B-C. (Hole 5 is shown on sections A-B and B-C).

mite, quite cherty in the bottom 100 feet. The top 30 feet contain large fissures filled with Devonian sand.

The Devonian rocks range from zero to about 150 feet thick over the area and are represented by the Cedar Valley and Wapsipinicon formations, both of Middle Devonian age. They generally consist of grayish to grayish brown finely crystalline limestone, with coarse fossils in the Cedar Valley portion. In places they are dolomitic. Scattered, fine to coarse, semi-rounded sand grains are common throughout and in some areas thin, local, sandstone lenses are developed.

The Grassy Creek shale is the basal portion of the Kinderhook-New Albany section in this part of Illinois. The shale is chocolate-brown, has a brown streak, and commonly a somewhat greasy or waxy appearance. Sporangites are common and helpful for identification. Toward the base the shale may be gritty, and at the base, between the shale and the Devonian limestone, the thin pyritic and quartzitic Sylamore (Hardin) sandstone is almost always present.

DISCUSSION OF CROSS-SECTIONS

The stratigraphic cross-sections are not intended to show present structure. We have used the base of the New Albany shale rather than sea-level as the datum plane to illustrate the stratigraphic conditions at the time deposition of the shale began. Correlations are based primarily upon characteristics shown in electric logs, which we believe are consistent with age and lithological correlations.

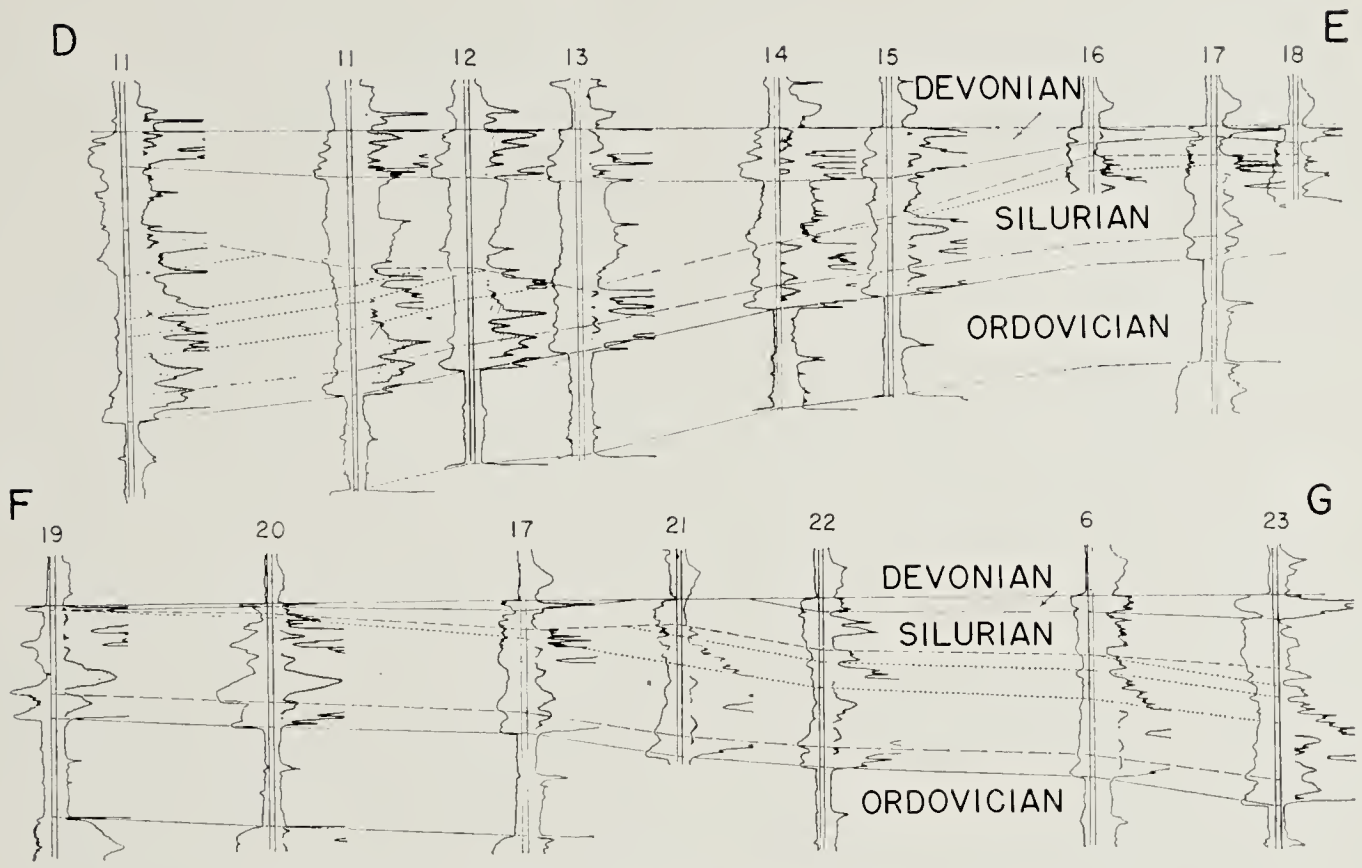

FIG. 3.—Stratigraphic cross-sections D-E and F-G.

The Maquoketa shale and the Lower Silurian (Alexandrian series) are uniform in thickness over the entire area, indicating that conditions were uniform during late Ordovician and early Silurian time.

Middle Silurian (Niagaran) strata above the Alexandrian show not only a variable over-all thickness at different places, but also considerable variation in the lithology and thickness of the several units.

The Niagaran section, as a whole, thickens to the south and east. However, the lower units thicken to the north and west. The lower portion is very characteristically indicated by high electrical resistance, not only here but over the entire basin. A short distance above this lower portion is one of the best electrical markers in the basin, commonly referred to as "3-kick," and directly below it is "2-kick," another recognizable unit (Fig. 2, hole 3).

In cross-section A-B-C, the first unit above the Alexandrian (indicated by the fine dashed line) is more than three times as thick at the north end (hole 9) as it is at the south end (hole 1). All the units in the lower portion of the Niagaran appear to have the same northward thickening, although some are cut out to the north, as shown on our cross sections. In the east-west cross-section F-G these same units thicken toward the west.

The upper part of the Niagaran maintains similar characteristics over a wide area. It is thickest in the middle portion of the north-south sections but, as indicated in cross-section F-G, it thins westward and is absent in Morgan County. Specifically, the thickest section is at hole 13 in T. 9 N., R. 5 W., and thins toward the east, north, and south from this point. We are not certain of conditions farther to the west. Lower Niagaran units approach the upper Niagaran unit with an angular relationship and appear to be truncated at their point of in-

System	Series	Formation
Mississippian	Kinderhook	New Albany (Grassy Creek)
?		
Devonian	Middle	Cedar Valley Wapsipinicon
Silurian	Niagaran	
	Alexandrian	Kankakee Edgewood
Ordovician	Cincinnatian	Maquoketa

Fig. 4.—Rock formations present in central Illinois.

tersection with its lower surface. If this surface be an unconformity, there was a period of uplift and erosion within Niagaran time, when several hundred feet of lower Niagaran sediments were removed before the upper unit was deposited. The position of this possible unconformity is indicated by the medium-length dashed line on the cross-sections.

Beds of Wapsipinicon and Cedar Valley limestone rest on the dolomite strata of Niagaran age. Because these Middle Devonian beds overlie Middle Silurian beds, it is obvious that there was an appreciable time interval between deposition of these formations. Devonian carbonate rocks are absent in three of the holes in Christian and Macon counties and the black shales rest directly on Niagaran dolomite.

The New Albany shale with the thin Sylamore (Hardin) sandstone at the base lies unconformably upon the beveled surface of both the Devonian and Silurian formations.

Conclusions

Critical examination of electric logs and assembly of cross-sections presented here furnish new data concerning the subsurface geology of this part of Illinois. These data also suggest possible new interpretations of stratigraphy and structural history of part of the rocks of the area. Although these suggested interpretations are as yet not sufficiently firm to replace earlier conclusions, it is our opinion that they are strong enough to merit careful consideration as an alternate hypothesis.

A recent report (Ball, 1952: 12-14, 58) on the Carlinville area, which lies just west of our D-E cross-section, stated that there is an unconformity between the Maquoketa shales of Ordovican age and the Alexandrian limestones of lower Silurian age, another unconformity between the Edgewood and Kankakee (Sexton Creek) formations of the Alexandrian series, and a disconformity between the Alexandrian and the overlying rocks of Niagaran age. Evidence from our cross-sections bearing on these matters is inconclusive. The uniform thickness of the Maquoketa formation and Alexandrian series shown on our cross-sections indicates that there was no significant differential erosion accompanying the several periods of emergence.

TABLE 1.—List of Wells in Cross-Sections.

No.	Company	Farm	Sec.	Twp.	Range	County
1.	Ashland & Nash Redwine..	#1 Rasler.....	21	6N	2W	Bond
2.	Calvert Drilling.....	#1 Webb.....	9	7N	2W	Montgomery
3.	Superior Oil.....	#1 Singler....	3	8N	2W	"
4.	Benedum-Trees.....	#1 Janssen....	3	10N	2W	"
5.	Rogers & Rogers.....	#1 Johnson...	27	12N	2W	Christian
6.	Sun Oil.....	#1 Ettinger...	8	13N	1W	"
7.	Jarvis.....	#1 Butcher...	21	15N	1W	"
8.	Sun Oil.....	#1 Graves....	3	16N	1W	Macon
9.	McCue.....	#1 Christensen	1	18N	1W	Logan
10.	Eason.....	#1 Mohme....	14	6N	5W	Bond
11.	Reznick.....	#1 Monke....	4	7N	5W	Montgomery
12.	Seaboard Oil.....	#1 Lay.....	20	8N	5W	"
13.	Calvert.....	#1 Hopkins...	24	9N	5W	"
14.	Gulf.....	#1 Brandon...	1	10N	5W	"
15.	Texas Co.....	#1 Long.....	27	11N	5W	"
16.	Graeling & Shanahan.....	#1 Guill.....	6	12N	5W	"
17.	Gulf.....	#1 Dambacher	15	13N	5W	Sangamon
18.	Roberts.....	#1 Shepherd..	25	14N	5W	"
19.	Panhandle Eastern.....	#1 Doolin....	16	13N	8W	Morgan
20.	V. S. & S. Drilling Co.....	#1 McNaught.	24	13N	7W	Sangamon
21.	Phillips Petroleum.....	#2 Pawnee*...	15	13N	4W	Christian
22.	National Associated.....	#1B Peabody Coal.....	33	13N	3W	"
23.	National Associated.....	#34 Lawrence.	9	13N	1E	"

*Structure Test.

The over-all thickness of the middle Silurian (Niagaran) is greatest toward the south and east, but beds in the lower portion of the Niagaran series thicken toward the north and west. This relationship suggests that the depositional basin during earliest Niagaran time lay northward rather than southward as one would conclude by considering total Silurian thicknesses.

Workman and Gillette (1956: 10, 12), in their discussion of the Kinderhook series, defined the Petersburg basin as the area lying northwest of the Vandalia arch and north of the Ozark uplift in which the Kinderhook strata are 200 to 225 feet thick. Presumably this basin originated during Kinderhook time and had a connection northwestward into Iowa. Our sections lie in the area northwest of the Vandalia arch and north of the Ozark uplift, and the northern and western wells are in the basin proper. It seems possible that the thickening of the lower Niagaran strata shown by our sections may indicate an earlier and larger ancestral Petersburg basin.

While not indicated by our electric-log cross-sections, the presence of an unconformity at the top of the Niagaran strata cannot be doubted. The time interval between the deposition of middle Silurian rocks and of the immediately overlying middle Devonian rocks is great and is represented in other areas by thick sedimentary sequences. Because of this known great time-interval, previous workers (Lowenstam, 1949:

9) believed that the over-all thinning of the Silurian rocks northward is due to bevelling during this period. The rocks which we call upper Niagaran have been considered a facies of rocks in the units we place in the lower portion of the Niagaran (Lowenstam, 1949 : Fig. 2, and 1950 : Fig. 2). It seems logical to assume that, if a sequence of truncated beds occurs below the middle Devonian contact, there should be considerable variation in the lithologic and electrical characteristics of the uppermost Silurian rocks along the line of cross-sections. However, the logs indicate a high degree of uniformity with variation only in total thickness of the Niagaran at any one locality. This uniformity has been attributed (D. H. Swann, pers. comm., 1957) to a weathering change of original lithologic types during the long period of erosion.

An alternate hypothesis that we judge to be worthy of consideration is implied by the cross-sections (Figs. 2 and 3). The medium-length dotted line is indicated as a surface of unconformity resulting from uplift and erosion during Niagaran time with truncation of the older Niagaran beds below this surface. This hypothesis assigns the beds above the unconformity to a younger age within the Niagaran; that is, these rocks were deposited upon previously bevelled earlier Niagaran rocks.

Such an unconformity accounts for the apparently anomalous variations in total thickness as opposed to the individual unit thicknesses. Subsequent deposition on this eroded surface possibly accounts for the uniform dolomitic character of the upper Niagaran unit.

If this hypothesis should prove to be correct, then the surface of unconformity may offer possibilities for the stratigraphic accumulation of oil at locally favorable places throughout the area.

Middle Devonian (Wapsipinicon and Cedar Valley) limestones rest unconformably upon the Middle Silurian (Niagaran) sequence. There is an area in Christian, Macon, and Sangamon c o u n t i e s where the Devonian and upper portions of the Niagaran rocks are absent (cross-section A-B-C, wells 7 and 8, and cross-section F-G, well 21) because of erosion following deposition of the Wapsipinicon and Cedar Valley formations. Whiting (1956) has shown that oil in the Christian County area is obtained from porous zones developed in the Silurian rocks during this erosional period. The absence of Devonian limestones here is probably due to re-uplift and erosion at the close of Middle Devonian time.

The Wapsipinicon and Cedar Valley limestones are sandy and variable in lithology, which suggests nearshore deposition. The Wapsipinicon is correlated with the Geneva dolomite and the lower part of the Grand Tower limestone, both of which are Middle Devonian in age. Oil production in the Salem Pool is at this horizon.

The New Albany (Grassy Creek) shale lies unconformably over all the area of this study. This shale is considered the most likely source of oil in Devonian and Silurian rocks with which it is in contact.

Publication of this manuscript is authorized by the Chief, Illinois State Geological Survey.

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SOURCE AND OCCURRENCE OF BRINES FOR WATERFLOODING IN ILLINOIS

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Introduction

Since 1943, Illinois oil-field operators have increased the demand for water for secondary recovery of oil through waterflooding. A recent inventory of Illinois waterflood operators shows that during 1956 nearly 30 million barrels of oil were recovered by injecting 289 million barrels of fresh and saline water into oil-producing formations (Pryor, *et al.*, 1957). Produced water (Fig. 1) is that water which is produced with and separated from oil. All water other than produced water is called make-up or supply water. It may be either fresh or brine. An attempt has been made (Fig. 2) to distinguish between produced and make-up brine. It is often difficult to do this because some operators consider all water that is not being produced in a particular flood project as make-up water, although some of it was produced in another project.

This paper describes, within the limitations of available information, the source and occurrence of brines in Illinois, problems involved in their development, and their potential as a source of water for waterflooding. Water used for pressure maintenance projects, dump floods, and brine disposal projects is not considered.

Stratigraphy and Water-Yielding Characteristics

In the Illinois basin many sandstones and limestones ranging in age from Cambrian to Pennsylvanian contain brines (Fig. 2). The distribution, thickness, composition, and permeability of these brine aquifers vary considerably throughout the area. In general, all these formations will yield fresh water at or near their outcrops along the margins of the basin, but within the basin they contain saline waters that become more mineralized with depth.

It is difficult to predict the water-yielding potential of the aquifers in the basin because their hydrologic characteristics are not well known. Waterflood operators are becoming increasingly aware of the need for these basic hydrologic data as they demand new and larger supplies of water. Without such data, our knowledge as to their potential is based on the assumption that if water is obtained from a formation, similar amounts can be obtained from it in other areas where similar conditions prevail. The "drying up" of brine-supply wells in some places demonstrates the lack of consideration of the geologic and hydrologic factors as they may affect the waterflood program. Such short-sighted-

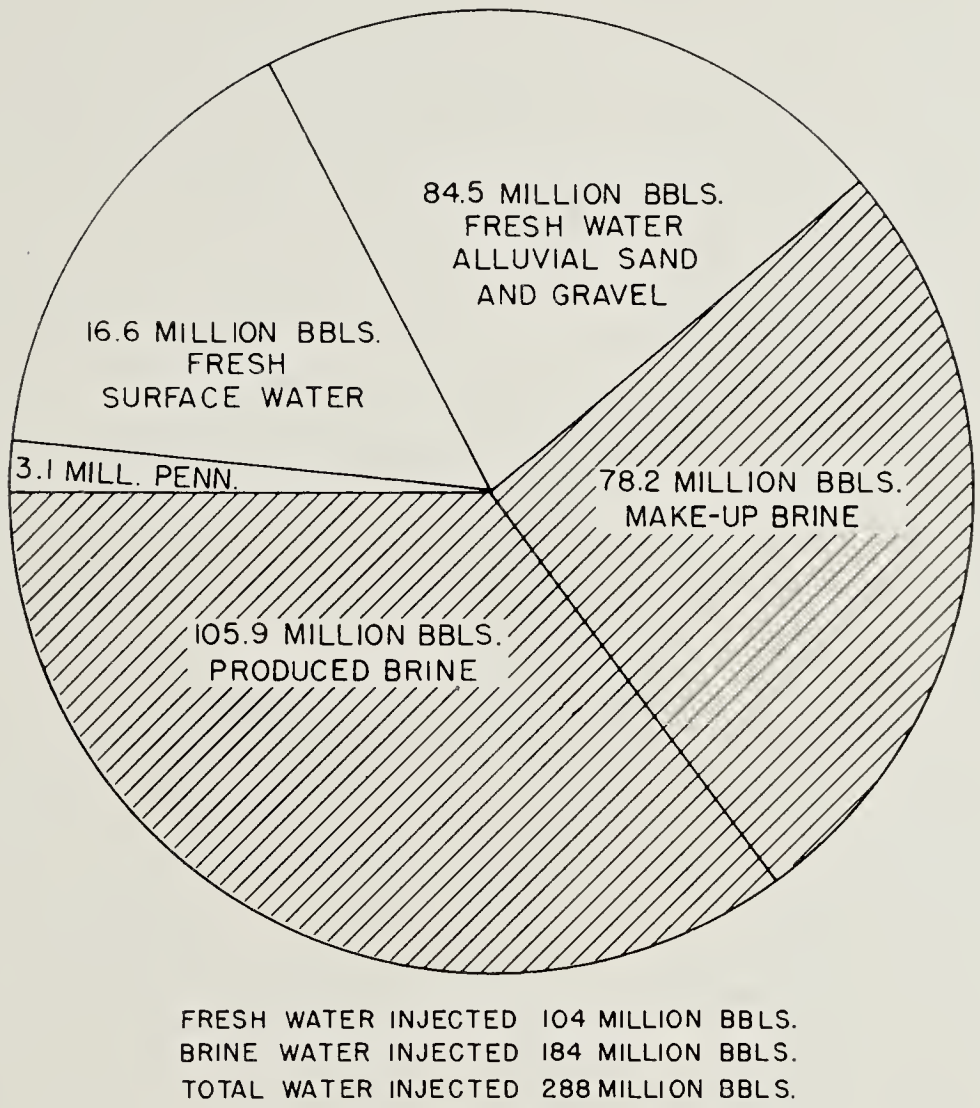

FIG. 1.—Chart showing distribution among sources of water used for waterflooding in Illinois during 1956.

ness and unnecessary expense can be avoided by conducting pumping tests on these formations to determine their specific capacity, storage coefficients, transmissibility, and other important hydrologic characteristics (Pryor, *et al.*, 1957:51-55).

The water-yielding potential of formations shown on Figure 2 may be roughly evaluated on the basis of present use. However, large quantities of produced water are being disposed of in brine-disposal projects. If this considerable but unknown amount of water were used for waterflooding, the data on produced water (Fig. 2) would be increased considerably in some instances.

Lower Paleozoic formations.—The Cambrian rocks are not shown in the column because their thickness and lithology are little known in the central part of the basin. In northern Illinois, Cambrian sandstones are important fresh-water aquifers. If Cambrian sandstones occur in the basin, and if brines are available from them, economic limitations of depth will determine their use.

At present only small amounts of fresh water are obtained from the St. Peter sandstone in its outcrop area along the western margins of the basin. None of this water is being used for waterflooding.

The Trenton limestone and dolomite, the Silurian limestone and dolomite, and the Devonian limestone all yield varying amounts of fresh water where they crop out along the western and southern margin of the basin. Water is obtained

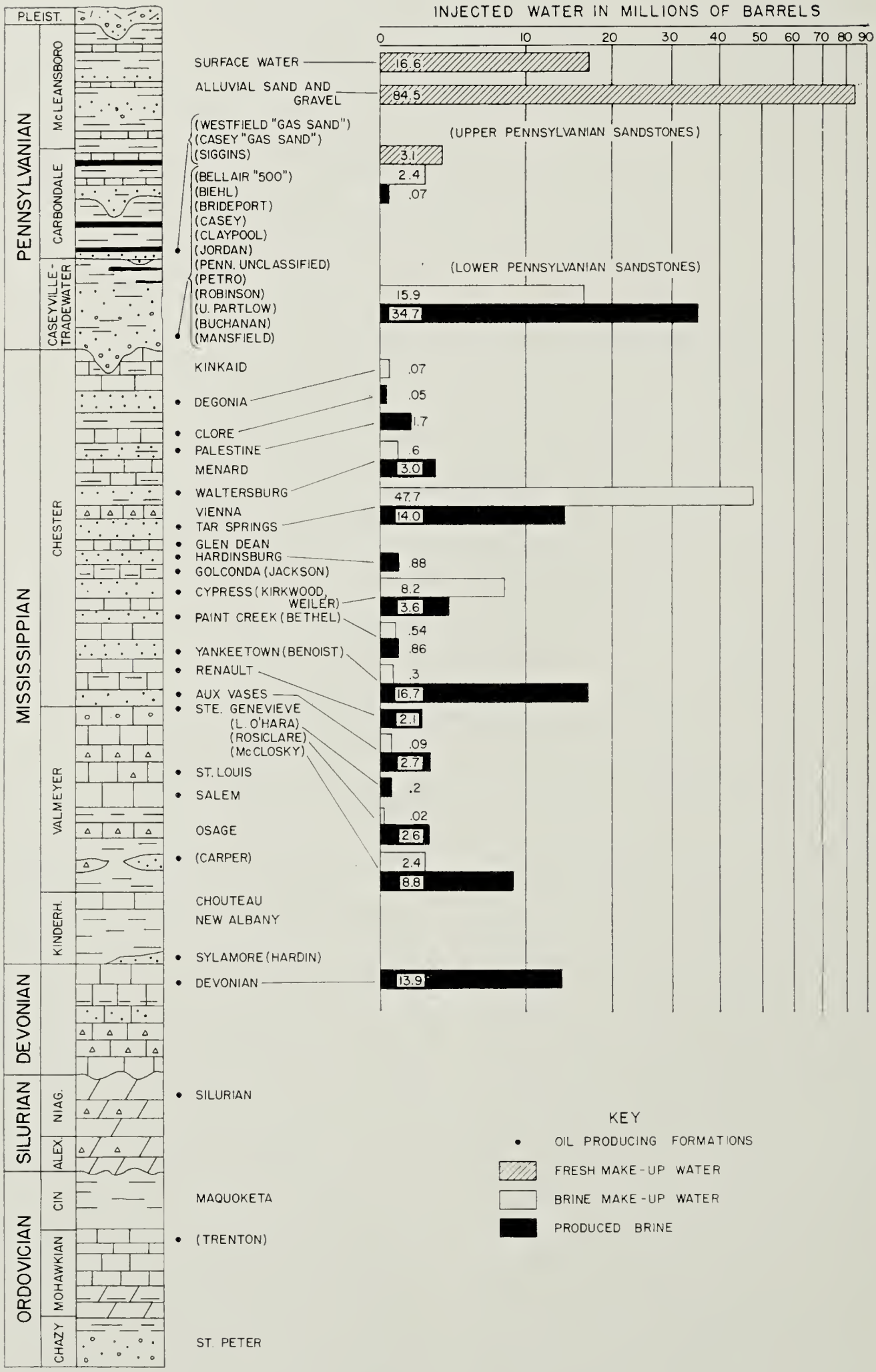

FIG. 2.—Generalized geologic column for the Illinois basin and chart showing oil-producing formations and the amount, type, and source of water used for waterflooding in 1956.

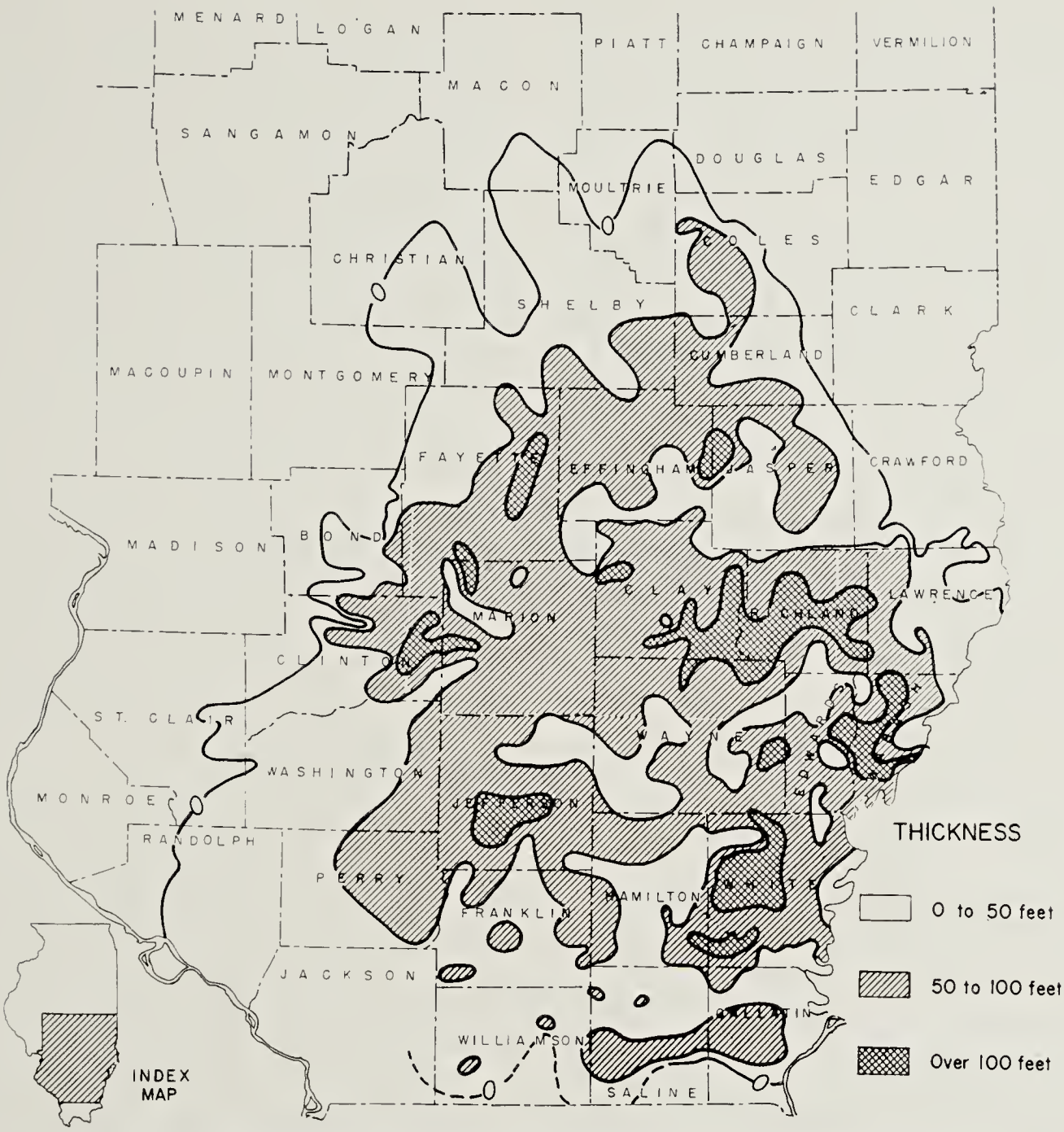

FIG. 3.—Approximate cumulative thickness of sandstone in the Tar Springs formation (from Pryor, *et al.*, 1957).

from joints, fractures, and solution channels. If these features are present in the deeper portions of the basin, then brines may be obtained from them, at least locally. Water is not being obtained from these deep aquifers because: 1) Sufficient quantities of water are economically withdrawn from shallower aquifers or surface reservoirs; 2) Waterflood projects have not been initiated in areas where these formations might be economically used; and 3) Oil drilling does not extend to these formations in deeper portions of the basin.

At present, Devonian strata are the only Paleozoic formations below the Mississippian rocks that yield large amounts of water for waterflooding. This is produced water, but it is likely that make-up brines could also be obtained from Devonian rocks in some fields.

Mississippian formations.—Widespread occurrence of shales excludes the lower Mississippian rock as sources of water. The permeable, oolitic Ste. Genevieve limestone is the lowest important Mississippian formation from which brine water is obtained. The "Rosiclare" and "Mc-

Closky'' aquifers are important sources of water for waterflooding in some localities. Large amounts of produced water are also obtained from them.

Permeable Chester sandstones are the most used brine aquifers in Illinois. They also yield the most oil. The most important Chester aquifers are shown in Figure 2. The Aux Vases, Renault, Benoist, Cypress, Tar Springs, and Waltersburg sandstones are all notable sources of produced brine, and the Tar Springs and Cypress sandstones are particularly important sources for make-up water.

Figure 3 shows cumulative thickness of sandstone in the Tar Springs formations. During 1956, flood projects of the Louden field withdrew about 43 million barrels of brine from the Tar Springs sandstone where it is 100 feet or more thick. This is the greater part of total Tar Springs brine used in all pools in the basin. The widespread occurrence elsewhere of thick Tar Spring sandstone suggests the great potential of this formation in other areas. The same conclusion can be drawn for certain other sandstones in the Chester group.

Pennsylvanian formations.—The Pennsylvanian rocks are characterized by alternating beds of shale, siltstone, limestone, coal, and sandstone. The lenticular sandstone formations of the lower part of the Pennsylvanian System are characterized by clean, coarse-grained quartzose sandstones, whereas the upper Pennsylvanian rocks generally contain finer grained sandstones with considerable amounts of clay, silt, and mica. Therefore, the lower Pennsylvanian formations are generally more permeable than the upper Pennsylvanian formations, although both are highly variable in permeability. Locally, well defined pre-Pennsylvanian drainage channels are superimposed on the underlying Mississippian surface. In these channels thick, permeable, basal Pennsylvanian sandstones were deposited (Siever, 1951).

Problems Concerning the Use of Brines for Waterflooding

Two types of problems associated with the use of brines for waterflooding are common to both brine and fresh-water supplies.

1. Several related geologic and hydrologic problems are: location of aquifers that yield sufficient quantities of water; construction of efficient water wells into these aquifers; and placement of wells to prevent well interference. Information concerning these factors can be obtained by basic geologic studies, by evaluation of driller's logs, electric logs, and sample studies, and by interpretation of pumping-test data.

2. Formational clogging may occur as a result of reactions between clay particles on sand-grain surface and injected water which can cause clay particles to separate from sand grains (Witherspoon, 1952). Brines are not always compatible with these clays and may cause clogging if certain components in the brines are adsorbed by the clay material (Grim, 1947).

Injection of saline water rather than fresh water is often advantageous when expandable type clays are present. Saline water generally has

less effect on the clay-mineral particles, whereas fresh water may cause expansion and dispersion of clay material (A. W. White, pers. comm.). Before initiating a waterflood, it is advisable to establish the character of the clays present in the oil formations and to evalute the possible effects injected waters may have upon these clays.

Other problems are for the most part unique with respect to brine supplies. These include:

1. Mixing of incompatible water. Only locally have brine supplies been avoided in Illinois because of their restrictive chemical nature. Recently developed water-treatment practices (Watkins, 1957) have allowed the use of all brines with the exception of those containing barium and, in part, high concentrations of iron. In these two instances, precipitates of iron sulfide (FeS) and insoluble barium sulfate ($BaSO_4$) have been produced. According to Squires (1951) acid treatments have restored intake rates by removing some of the iron precipitate. Calgon and calcium hypochlorite have also been added by operators to prevent iron precipitation. Recent investigations by the Pure Oil Company (Bernard, 1957) indicated that the mechanics of water displacement prevent the mixing of injected water to any great extent with water in the oil reservoir during a water drive. In the zone where incompatible waters do mix, only negligible reductions in pore space will result.

In Bernard's opinion, this accounts in part for the success some operators are having at present with incompatible waters. However, if incompatible waters are mixed at the well head or within the injection well, precipitates should be anticipated. These precipitates will be filtered out at the sand face of the injection well and will reduce injection rates.

With further study it may prove feasible to use those brines which were previously considered unsuitable for waterflooding.

2. Corrosion of oil-field equipment by chemically active constituents in brines. This is of great economic importance to oil field operators. Measures being taken to minimize the corrosion problems include: a) Use of corrosion inhibitors in brine. Their use in other areas was discussed by Breston (1949), Heck *et al.* (1949) and Robinson (1956); b) Use of aeration equipment and baffled brine-setting pits to remove chemically active gases (CO_2, H_2S). According to Watkins (1957), a new method of removing hydrogen sulfide and oxygen from water employed elsewhere is by countercurrent scrubbing in a packed tower using synthetic or natural combustion-exhaust gases. Applications and principles have been discussed by Doscher and Tuttle (1954) and Crawford (1955). A similar submerged-burner method was discussed by W. J. Hart and R. T. Wingate (unpubl., 1955); c) Use of non-corrodible equipment, such as wooden brine-treatment tanks, plastic pipes, non-corrodible liners made of plastic or cement-asbestos, and certain equipment made from corrosion-resistant alloys; and d) Cathodic protection.

Conclusion

Several factors allow brines to compete economically with fresh-

water supplies in Illinois despite more elaborate water-treatment requirements.

1. Competition for brines is limited to waterflood operators as compared to competition among a host of fresh-water users.

2. Brines are readily available from numerous formations throughout the Illinois basin. These formations are widespread geographically and contain adequate supplies of water for waterflooding.

3. Produced brines in increasing quantities should be anticipated during the advanced life of most Illinois oil-pools. Since this water has to be disposed of without contaminating potable water, it may be advantageous to invest in water-treating facilities capable of treating these brines and using them for waterflooding, thus alleviating make-up water demands.

4. Brines are often chemically more acceptable than fresh water.

5. Some dry holes and abandoned oil wells may be converted to brine-supply wells, thus reducing development costs.

6. Excess quantities of brines are often in demand for use by neighboring operators.

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AGE AND STRATIGRAPHIC RELATIONSHIP OF THE CALOOSAHATCHEE MARL OF FLORIDA

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Introduction

Lower shell beds exposed along Caloosahatchee River in southern Florida were assigned a Pliocene age by Heilprin (1887:32) in 1886 and named the Floridian beds. A year later William Healy Dall (1887) changed the name of the formation to the Caloosahatchie beds and confirmed Heilprin's assignment as Pliocene. Since that time the deposits have been studied by many geologists, and numerous papers have been written concerning the Caloosahatchee marl. All subsequent investigators have agreed with Heilprin and Dall and classified the Caloosahatchee marl as Pliocene in age. This age-assignment has been based primarily on the nature of the molluscan faunal assemblages and secondarily on the incorrect assumption that the formation is unconformably overlain by beds of early Pleistocene age.

My investigations and those of several other workers during the past five years have uncovered evidence which strongly suggests that the Caloosahatchee marl should be reclassified as a Pleistocene deposit, probably post-Kansan and pre-Wisconsinan in age. The most compelling evidence supporting a Pleistocene classification is derived from the vertebrate remains contained in the upper beds of the Caloosahatchee marl. Most of the vertebrate species have never been recorded from pre-Pleistocene deposits.

I wish to express my sincere thanks to those who have made contributions to this study. The Florida Geological Survey, under the direction of Dr. Herman Gunter, paid field expenses and made available the facilities of the Survey. Mr. Herbert Winters identified most of the vertebrate remains and supplied many valuable data concerning the stratigraphy of Florida. The corals were identified by Dr. John Wells of Cornell University.

Distribution and Nature

The Caloosahatchee marl underlies the surface of much of southern Florida (Fig. 1). The type deposits are exposed along Caloosahatchee River which flows westward from Lake Okeechobee. The Caloosahatchee marl extends along the west coast of Florida as far north as north St. Petersburg. The formation also has been recognized in subsurface at approximately N.29.5°. Exposures along St. Mary's River in Nassau County in northeastern Florida that have been assigned to the Charlton formation probably represent a facies of the Caloosahatchee marl.

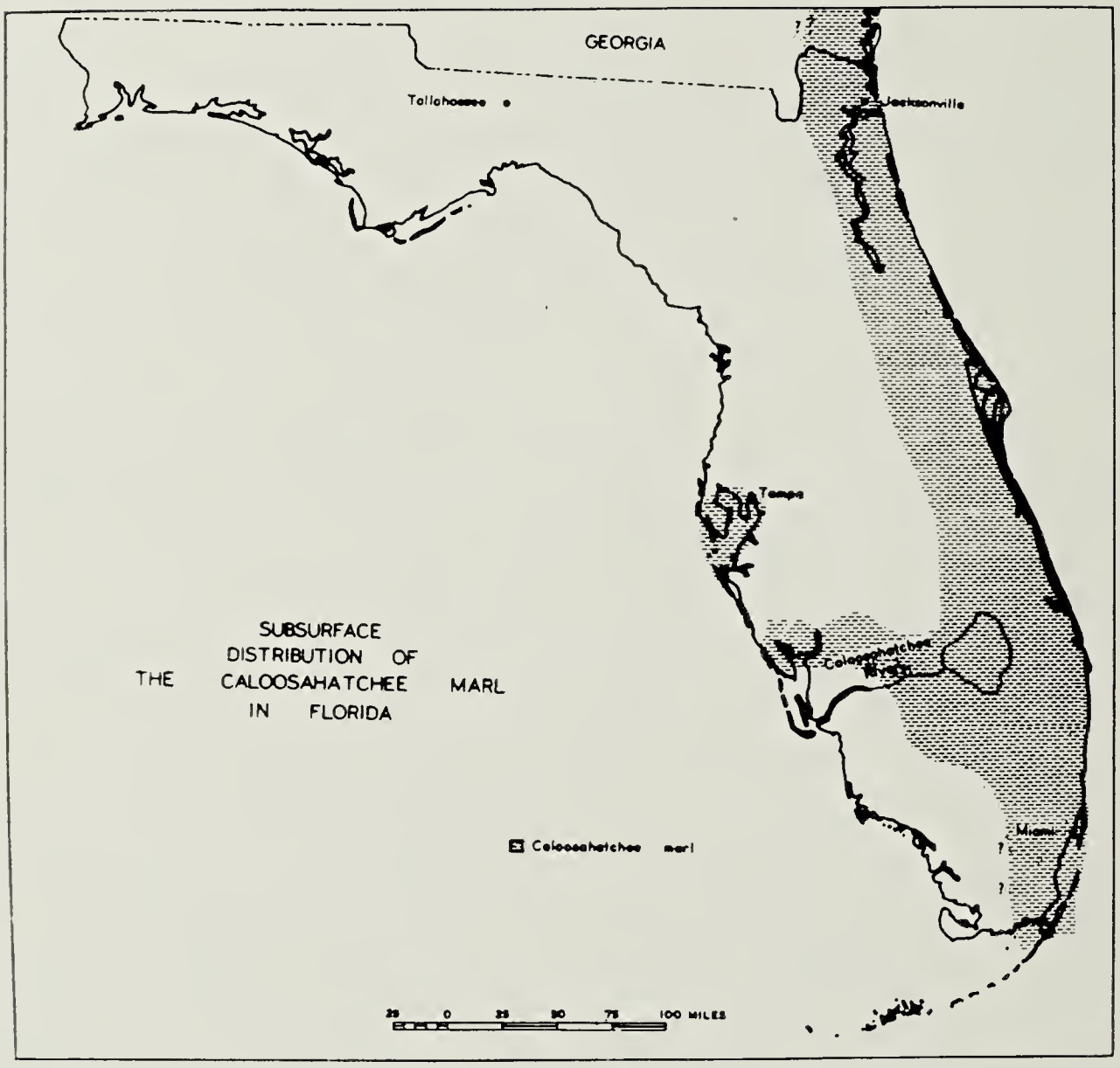

FIGURE 1.

Typically, beds of the Caloosahatchee formation consist of marls composed primarily of quartz sand, silt, clay, and shells, and a few beds of sand. Most of the strata are soft or only slightly indurated, but some are calcareous and very hard. Most layers are moderately to abundantly fossiliferous, although some, especially sands, are almost or completely devoid of fossils. Fresh exposures are generally light-colored with white, light gray, cream, and buff predominating. In subsurface many sand layers are light green to olive green. Weathered marls are usually light to dark gray on the surface.

In most areas that I studied, the Caloosahatchee marl is less than 50 feet in thickness and averages less than 40 feet. In many places the formation is absent, either because it was never deposited or has been eroded.

Stratigraphic Relationships

Upper and lower limits.—I have observed the base of the Caloosahatchee marl only in southern Florida, where it lies unconformably on the heavily dissected Tamiami formation of late Miocene age. Along the Caloosahatchee River and to the south, the Caloosahatchee deposits are thickest over the old Tamiami valleys, and they thin or pinch out over the old hills and divides. Little is known about the base of the Caloosahatchee marl to the north,

but presumably the formation is unconformable with underlying beds throughout the state. In wells in Seminole County it rests on the Ocala (Eocene) limestone (Cooke, 1945: 215).

The Caloosahatchee marl is exposed at the surface only in canals, pits, and river banks. Everywhere it is overlain unconformably by late Pleistocene deposits. In the type locality the overlying beds most commonly belong to the Ft. Thompson formation, but in some places the formation is overlain by Pamlico sands. To the south, east, and southeast the overlying beds belong either to the Anastasia formation, Key Largo limestone, Miami oolite, or one of the late Pleistocene terrace sand formations.

Correlation with other units. — Several formations have been considered to be facies of the Caloosahatchee marl, representing varied deposits of Pliocene age. Among these is the Tamiami formation (discussed above) now regarded as late Miocene in age. Other so-called facies or correlatives include the Bone Valley, Charlton, Alachua, Citronelle, Waccamaw, and Croatan formations. The Bone Valley formation of west-central Florida was considered by Cooke (1945: 18) to represent an estuarine facies of the Caloosahatchee, although the formations are not known to intergrade or interfinger. The vertebrate fossils of the Bone Valley beds include a mixture of Pliocene and Miocene species, none of which is known from the Caloosahatchee marl. With little doubt the Bone Valley beds are considerably older than the Caloosahatchee formation, and they possibly represent an estuarine facies of the Tamiami formation.

The Alachua of west-central Florida is a residual formation derived from weathering of pre-existing formations. The only fossils are vertebrates which comprise a mixture of Miocene, Pliocene, and Pleistocene species and show no close relationship to the vertebrate species of the Caloosahatchee marl.

Cooke (1945: 227-229) and Cole (1944: 23) seem to have correlated correctly the estuarine Charlton formation of northeastern Florida with the Caloosahatchee marl, although the Charlton could represent a slightly younger deposit, judging from its molluscan assemblage.

The Citronelle formation has been traced into northwestern Florida at least as far as Appalachiocola River and may be represented also by red sands in central Florida. Berry (1916: 195) dated the formation as late Pliocene on the basis of plant fossils contained in clay at the type locality. Roy (1939: 1557) believed that the plant-bearing clay was faulted up against the Citronelle gravel and that, therefore, it is older than the gravel. In Mississippi the Citronelle overlies the Graham Ferry formation, which is supposed to be Pleistocene in age, and the Citronelle is there considered of undoubted Pleistocene age (Brown, *et al.*: 45-59). The "Citronelle" deposits in central Florida were thought by Cooke (1945: 231) to comprise a Pliocene near-shore and beach facies of the Caloosahatchee marl. No intergradation of the two formations has ever been observed.

Fossils are rare in the Citronelle of Florida, but according to Cooke

and Mossom (1929 : 147) a few poorly preserved casts of marine gastropods and pelecypods were collected in Escambia County from beds that belong to the Citronelle. The occurrence of the Miocene *Ostrea* sp. *cf. O. westi* Mincher is reported from Okaloosa County by Cooke (1945 : 231), but he is uncertain about the exact stratigraphic position of the fossils; it is possible that the oysters were not in the Citronelle beds.

Most of the "Citronelle" strata of central Florida appear to lie above the 100-foot contour line, or above the Wicomico terrace, and, therefore, they could represent a facies of the Caloosahatchee marl. If this is true, at least the so-called Citronelle of central Florida should be classified as Pleistocene in age.

The Waccamaw and Croatan formations of North Carolina and South Carolina were correlated by Cooke, Gardner, and Woodring (1943) with the Caloosahatchee marl. The Molluscan assemblages of the Caloosahatchee marl in Putnam and Volusia counties of east-central Florida are intermediate between the tropical assemblages of the type Caloosahatchee to the south and the temperate assemblages of the Waccamaw and Croatan formations. It appears then that the Waccamaw and Croatan beds represent a cooler water facies of the Caloosahatchee marl.

Age

Evidence from the invertebrate fauna.—The molluscan fauna of the Caloosahatchee marl is distinctive, containing many species not known from other deposits. Dall (1903 : 1604-1605) recognized 639 species of mollusks as occurring in the formation, of which 314 (49%) are also Recent. Thus, on the basis of percentage of extinct molluscan species the Caloosahatchee seems to have been correctly placed in the Pliocene. However, differences between many Caloosahatchee species and their present-day descendants are slight and are probably of no more than subspecific value. Other species thought to be extinct probably survive in more southern latitudes where they have not yet been observed. It appears probable then that considerably less than 51% of the species are extinct. In addition, none of the Caloosahatchee molluscan species is elsewhere restricted to deposits of undoubted Pliocene age.

Foraminiferans are relatively abundant in the Caloosahatchee marl, but studies by Cole (1931) and Cushman and Ponton (1932) failed to demonstrate important differences between late Miocene, Caloosahatchee, late Pleistocene, and Recent assemblages. A more recent study of the foraminifers has led Puri (1956, pers, comm.) to assign at least the upper Caloosahatchee beds to the Pleistocene.

Wells (1955, pers. comm.) considered several species of corals in the upper Caloosahatchee beds to be of late Pliocene age or younger. Two of the coral species are restricted to the Caloosahatchee marl and, on this basis, were judged by Wells to be Pliocene in age. Two species are restricted to the Pleistocene and Recent, and one species ranges from Miocene to Recent. If the two species restricted to the Caloosahatchee be omitted from consideration, then

it seems that the coral fauna represents a Pleistocene rather than a Pliocene age.

No attempt has been made to analyze in detail the echinoid fauna; however, the largest and most conspicuous species in the formation is *Clypeaster rosaceus* which also occurs in the Recent fauna and apparently is unknown from beds older than the Caloosahatchee marl.

The invertebrate fauna does not seem to offer a definite solution to the problem of the age of the Caloosahatchee marl. Most species, however, are known to occur in late Pleistocene or Recent deposits, and those restricted to the Caloosahatchee formation offer conclusive evidence neither for nor against a Pleistocene age.

Evidence of the vertebrate fauna. —The vertebrate assemblage which I collected from the type Caloosahatchee marl presents convincing evidence of Pleistocene age for the formation. There is no doubt that the bones were collected in place, and most of them were covered by several feet of marl and limestone bearing many of the most typical Caloosahatchee molluscan species. Most of the fossil vertebrates were collected from an upper shell bed, but some were found in the lower beds. The Caloosahatchee vertebrates are:

Alligator mississippiensis
Cetacean remains
Equus leidyi
?Holmesina septentrionalis
Odocoileus sp.
?Machrochelys temminki
Tanupolama sp.
Testudo sellardsi
Trachemys sculpta

The cetacean remains are being studied by Dr. Remington Kellogg of the U. S. National Museum in Washington, D. C.

None of the Caloosahatchee vertebrates are restricted elsewhere to Pliocene deposits, and in fact most are known only from the Pleistocene. According to Savage and Winters (1955, pers. comm.) ". . . one of the species of turtles is still living in Florida, and the other two are found only in Pleistocene and early Recent deposits. The equid teeth are indistinguishable from those of the so-called *Equus leidyi,* the medium sized, late Pleistocene and early Recent horse. The Chlamytheriinae seem to be restricted to the Pleistocene of North America. The evidence is strongly in favor of a post-Blancan age for at least the upper part of the Caloosahatchee formation, and it possibly dates from one of the interglacial stages when the sea level stood some 15 to 20 feet higher than at present."

Winters (1956, pers. comm.) has found no record of either *Equus* or a chlamytherid from the Blancan faunas. The earliest record of *Equus* known to him is from late Kansan deposits of the Nebraska-Kansas area and there is no known pre-Sangamonian record of the chlamytherid from North America. The giant armadillo, *?Holmesina septentrionalis,* has been recorded from 18 to 20 localities in Texas, Florida, Oklahoma, and Mexico, and all localities, except three where reworking has occurred, present strong evidence of Sangamonian or later age.

The Caloosahatchee fish and reptile fossils are considered by Auf-

fenberg (1956, pers. comm.) definitely to represent a Pleistocene age.

The vertebrate species, accordingly, present strong evidence of a post-Kansan age for the Caloosahatchee beds and the presence of the giant armadillo points to a Sangamonian or later age.

Relationship to Pleistocene shorelines. — The type Caloosahatchee marl contains a tropical molluscan assemblage which probably lived during a warm interglacial stage. If, as the vertebrate fauna suggests, the formation is no older than Kansan, then it must be assigned either to the Yarmouthian or Sangamonian interglacial stage. The inland limits of known Caloosahatchee deposits, as shown by Cooke's geologic map of Florida (1945), correspond closely to the Wicomico and Okefenokee shorelines as distinguished by MacNeil (1949) but appear to coincide most closely with the Wicomico at an elevation approximately 100 feet above present sea level. The Wicomico is regarded as Sangamonian in age (MacNeil, 1949: 99; Cooke, 1945: 17; Vernon, 1951: 21-27), and the Okefenokee is classified as Yarmouthian by MacNeil (1949: 99). It is possible that both shorelines were formed by successive stands of the Caloosahatchee sea during the same interglacial stage. Winters (1956, pers. comm.), however, thinks that the Okefenokee shoreline is Aftonian. This opinion is based on the occurrence near Brewster, Florida, of Blancan vertebrates just below the 150-foot contour.

Paleoecological studies indicate that the middle (Bee Branch, Table 1) member of the Caloosahatchee marl in southern Florida was deposited in an offshore continental shelf environment where the water depth probably exceeded 15 fathoms. The upper shell bed was probably deposited closer to shore in shallower water. If the water depth of the Caloosahatchee sea were approximately 90 to 100 feet where the middle member was being deposited, the corresponding shoreline should have closely approximated the level and outline of the Wicomico shoreline. As shown by MacNeil's map (1949), the distance is approximately 30 miles from the Caloosahatchee type area to the nearest point on the Wicomico shoreline. All of the lower Caloosahatchee beds appear to have been deposited in shallower water than the strata of the Bee Branch member, and, therefore, most traces of additional Caloosahatchee shorelines probably have been destroyed.

TABLE 1.—Stratigraphy of the Caloosahatchee River Area, Southern Florida.

Age			Formation
NEOGEN	Pleistocene	Wisconsinan	Lake Flirt marl Pamlico formation Ft. Thompson formation Coffee Mill Hammock marl member Okaldakoochee marl member
		Sangamonian	Caloosahatchee marl Ayers Landing member Bee Branch limestone member Ft. Denaud member
	Miocene	Pontian?	Tamiami formation

Summary

1. The Caloosahatchee marl rests unconformably on dissected strata of late Miocene or earlier age and is in turn unconformably overlain by beds deposited during the late Pleistocene.

2. The Tamiami and probably the Bone Valley and Alachua formations are older than the Caloosahatchee marl. The Charlton, Waccamaw, and Croatan formations are probably true facies of the Caloosahatchee. The relationship of the "Citronelle" of central Florida is uncertain, although it is possibly a near-shore or beach facies of the Caloosahatchee marl.

3. On the basis of faunal, paleogeographic, and paleoecological evidence, the Caloosahatchee marl seems to be Kansan or younger in age. The presence of *Equus leidyi* in the middle and upper members dates the Caloosahatchee marl as Post-Kansan, and the remains of *?Holmesina septentrionalis* in the same beds suggest that formation should be assigned to a Sangamonian or later age.

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CLAY MINERAL COMPOSITION OF CALCAREOUS TILL IN NORTHWESTERN PENNSYLVANIA

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Introduction

The clay mineral content of more than 200 samples of calcareous till in northwestern Pennsylvania has been determined. During the past several years George W. White and his associates have mapped the Pleistocene deposits in northeastern Ohio and northwestern Pennsylvania and collected more than 800 samples of calcareous till. These samples are being studied to determine total size-distribution (White and Shepps, 1952; Shepps, 1953), carbonate content, heavy-mineral content, till fabric (Sitler and Chapman, 1955), clay-mineral composition (Droste, 1956a), and clay-mineral weathering sequences (Droste, 1956b).

Each cross on Figure 1 represents a location where one or more calcareous tills were sampled. The samples were obtained from cut banks of streams, road cuts, recent excavations, and auger or shovel holes. In all instances the samples were taken from Horizon 4 (calcareous, oxidized, brown till) or Horizon 5 (calcareous unoxidized gray till). With the completion of this study, the clay-mineral composition of Pleistocene deposits will be known for an area of more than 6000 square miles in the Allegheny Plateau of northeastern Ohio and northwestern Pennsylvania.

Pleistocene Geology

Leverett's reports of 1902 and 1934 summarized the earlier work and described his morphological studies. Shepps (1955) studied the glacial deposits along the Pennsylvania-Ohio border, and during the past three summers Professor White and his associates, R. W. Sitler, J. C. Tharin, and the authors have studied in detail the Pleistocene drift of the area shown on Figure 1.

The oldest Pleistocene deposits of this area are distributed as indicated on Figure 1. These deposits are now believed to be Illinoian in age. A few possibly pre-Illinois terrace deposits may exist beyond the Illinoian, but no pre-Illinoian till has been found beyond the Illinoian boundary.

The oldest till of Wisconsin age in the area underlies younger Wisconsin drift except in a few places (White and Shepps, 1952: 1388). It is similar to till called Tazewell (White, 1953: 39, pl. 26) at the surface in the Akron, Ohio, region and underlying younger till elsewhere in northeastern Ohio.

Younger Wisconsin tills have been traced from northeastern Ohio where they have been assigned a Cary age (White, *op. cit.*). Four post-Tazewell till sheets have been differentiated: 1) till extending from the Wisconsin boundary almost to the De-

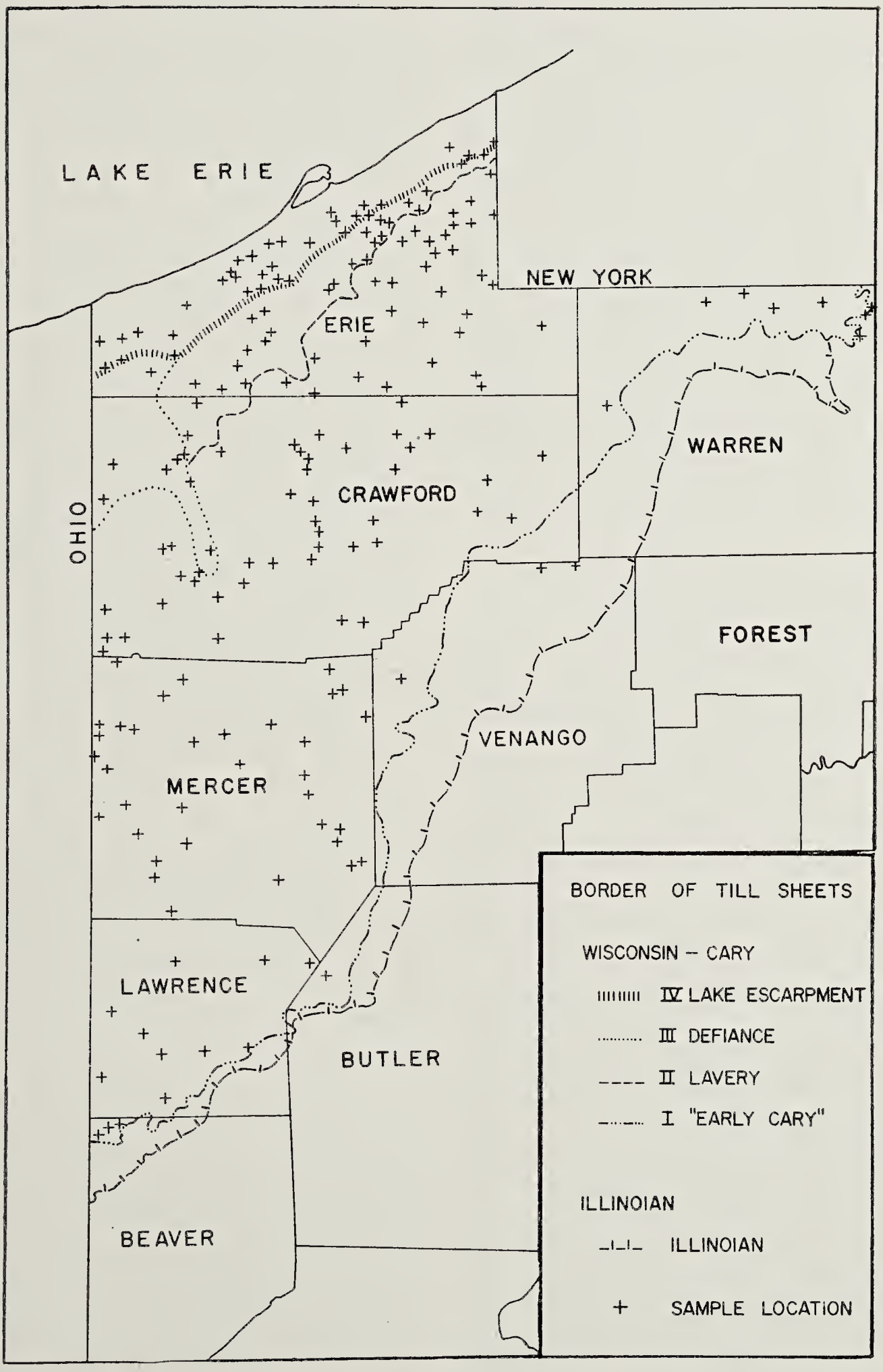

FIG. 1.—Drift sheets of northwestern Pennsylvania and sampled locations. Boundaries from work of White, Droste, Shepps, and Sitler.

fiance moraine (called "Early Cary" in Ohio); 2) narrow band of till just south of the Defiance Moraine and closely related to it (recognized only recently in Ohio, "Lavery" of Shepps, 1955); 3) sheet of clayey till from the Defiance moraine to the Lake Escarpment moraine system ("Late Cary" of White, 1953); and 4) the Lake Escarpment moraines.

Outcrops in which multiple tills are exposed are not common throughout northwestern Pennsylvania, but enough sections have been found to establish the Cary substages just described.

Laboratory Procedure

Oriented aggregates of the fine grain-sizes of each sample were made on glass slides (Grim, 1934), and diffraction patterns were obtained on a XRD-3 General Electric recording defractometer using filtered copper radiation. In addition to the air-dried samples, spectrometer traces were made on slides treated with ethylene glycol, NH_4Cl, and heated to 450° C.

Initially, the less-than-one micron fraction was separated from 40 samples by sedimentation in water without the use of dispersing agents and without acid leaching to remove carbonates. The less-than-eight micron fraction from another part of these same samples was obtained in the same way, and the spectrometer traces of the two size-fractions were compared. Except for the great increase of quartz and calcite lines very little difference could be seen between these size-fractions. Since the less-than-eight micron fraction requires less time to obtain, it was used to determine the clay-mineral composition of the remaining 160 samples. This procedure is the same as the one used in the study of the clay-mineral composition of tills in northeastern Ohio (Droste, 1956a).

Discussions and Conclusions

In all samples a peak due to chlorite occurs between 14.2Å and 14.6Å. The intensity and sharpness of this peak is quite variable and changes shape and position after glycol treatment, NH_4Cl treatment, and heat treatment. The more intense and sharp the peak is in the air-dried, untreated sample, the less it is modified after glycolation, NH^+_4 saturation, and heat treatment. The 14Å peak remains essentially unchanged in gray calcareous samples (Horizon 5), indicating the presence of well-crystallized chlorite.

In the brown calcareous samples (Horizon 4) the nature and modifications of the X-ray patterns after treatment with ethylene glycol, NH_4Cl, and heat depend upon where the sample is taken within Horizon 4. The nearer the sample is taken to Horizon 5, the less the peak characteristics change after the various treatments.

In the lower Horizon 4 samples the 14Å peak in the air-dried slide is as intense as but broader than in the Horizon 5 sample. The peak in these samples is partially lost after heating and remains essentially unchanged after glycolation and NH_4Cl treatment. The 14Å peak from a middle Horizon 4 sample is less intense and broader than in the lower Horizon 4 sample. The peak shifts to 15Å after glycolation, to 13.2Å after NH_4Cl treatment, and is completely lost after heating to 450°C.

The 14Å peak of a sample of upper Horizon 4 is broader and less intense than in the sample taken from the middle of Horizon 4. This peak may shift as high as 15.8Å after glycolation and as low as 12.6Å after NH_4Cl treatment. The nature of the 14Å peak (and appropriate higher orders) in Horizon 4 samples indicates that the well-crystallized chlorite of Horizon 5 is gradually hydrated. The hydration occurs by protons joining hydroxyls in the brucite sheets of the chlorite, and this leads to a mixed, layered, vermiculite—chlorite clay mineral. The hydration of every brucite sheet does not start at the same time—nor does every layer hydrate at the same rate—so that "islands" of magnesium ion surrounded by H_2O "grow" at random in the brucite sheet. It is important to point out that clay-mineral alteration begins in the lower part of Horizon 4.

A sharp, intense 10Å peak with appropriate higher orders is present in all samples, indicating the presence of illite. In the gray calcareous samples of Horizon 5 and in the samples taken in the lower part of brown calcareous Horizon 4 the 10Å peak in the air-dried samples is asymmetrical on the low-angle side (high d-spacing side) of the peak. The loss of this asymmetry after ethylene glycol and heat treatment indicates that some of the illite is hydrated. This hydration has probably occurred because of the removal of some of the potassium ion and entrance of water between the mica sheets. The removal of potassium ion from between the mica sheets is completely random, and in the samples taken from the upper part of Horizon 4 a mixed layering of illite-montmorillonite is very evident.

A 7Å peak is found in all samples. In almost all cases the characteristic of the 7Å peak can be explained as the (002) order of the 14Å - chlorite peak. In a few samples the entire diffraction diagram gave slight hints of the presence of kaolinite, but this is to be expected because of the tremendous variety possible in chlorites. Until a fool-proof method is devised to identify kaolinite in the presence of chlorite, small amounts of kaolinite will be missed when it is mixed with large amounts of chlorite. Kaolinite could not be definitely identified in the samples taken in Pennsylvania. Evidence is present that kaolinite occurs in the samples of tills of the same age in northeastern Ohio (Droste, 1956a), but as the Ohio-Pennsylvania state line is approached the kaolinite content of the tills in Ohio decreases. This disappearance of kaolinite in Pennsylvania may be a reflection of the clay-mineral variation in the composition of the local bedrock.

The approximate mean abundance of illite and chlorite in the samples studied is 60% and 40%, respectively. The amount of illite varies between 50 and 70% and the amount of chlorite varies between 50 and 30%. The quantitative estimation of the clay-mineral composition was made by the method described by Johns, Grim, and Bradley (1954).

Several complete weathering profiles of Wisconsin age were sampled to study the clay-mineral alteration throughout this entire profile. The data obtained from this study will not be presented here, but the alteration of the clay minerals does follow

the same general scheme already described for tills of the same age in Ohio (Droste, 1956b).

All these studies show again that, to understand completely the alteration of clay mineral by weathering in calcareous till, a sample of Horizon 5 must be included.

Summary

The clay-mineral composition of all fresh (Horizon 5) unoxidized, unleached tills of Illinoian and the five different episodes of Tazewell and Cary time is illite and chlorite. Unlike some of the tills of the same age in Ohio, none contain kaolinite in sufficient amounts for positive identification.

The clay-mineral composition of the calcareous, oxidized (Horizon 4) tills is variable and entirely dependent on the amount of alteration by weathering of the illite and chlorite present in Horizon 5.

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FAULTING IN THE POMONA AREA, JACKSON COUNTY, ILLINOIS

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Introduction

Location and geologic relationships.—The Pomona Area is near the Union-Jackson County line in the Shawnee Hill section of southwestern Illinois on the southern edge of the Illinois Basin (Fig. 1). The rocks of the area belong to the Chesteran Series of Late Mississippian age and to the Caseyville group of Early Pennsylvanian age. A major unconformity marks the Mississippian-Pennsylvanian contact throughout the region and is locally an angular relationship.

Structurally the Pomona Area is complex. The major structural features are apparently related to the Rattlesnake Ferry Fault (Ste. Genevieve Fault) which is about two miles south of the area studied. This large fault was active in the post-Chesteran — pre-Pennsylvanian interval and during post-Pennsylvanian time (Weller, 1940:51). The strata studied appear to have been strongly affected by fault activity in both post-Chesteran—pre-Pennsylvanian and post-Pennsylvanian time.

Previous investigations in the area.—Preliminary areal geologic maps and structural geologic maps of the Pomona Area have been compiled in the past by the following men: St. Clair, 1916; Ekblaw, 1925; Weller, Ekblaw, and Savage, 1940.

The pertinent literature and maps published in the past were carefully examined and field re-examination of the mapped area was made. In some places interpretations differ from those made prior to this investigation.

Field work for this investigation was begun in the fall of 1956 and continued throughout the winter of 1957, as part of a mapping project being conducted by the Geology Department of Southern Illinois University in cooperation with the Illinois Geological Survey. The area was carefully covered on foot in an effort to search out every outcrop, and thus compile a detailed geologic map.

Dating of Strata

Repetition of lithologically similar sediments imposes some difficulty in the proper identification of stratigraphic units (Table 1). The absence of good "marker beds" has necessitated analysis of gross lithologic aspects and stratigraphic relationships and the use of ostracodes as index fossils to establish the true age of the strata in the area. The ostracodes were collected from the shales and weathered limestones of the Kinkaid and Clore formations where they were available. Identification of ostracodes was based on "Chester ostracodes of Illinois" (Cooper, 1941).

TABLE 1.—Geologic Column of the Pomona Area.

		Formations	Thickness in feet	Lithology
Pennsylvanian	Caseyville Group	Drury shale, sandstone....	70-100	sandstone and shale; interbedded
		Lick Creek sandstone.....	40-100	sandstone; massive, conglomeratic
		Wayside shale, sandstone..	0-60	sandstone; fine-grained, thin-bedded; locally absent
		Unconformity----------		
Mississippian	Chester Series	Kinkaid limestone.....	0-70	limestone; massive, cherty, fossiliferous; locally absent
		Degonia sandstone.....	40-100	sandstone; massive, thin-bedded
		Clore formation.....	20-65	shale; calcareous; and limestone; dark, dense, fossiliferous
		Palestine sandstone.....	20-30	sandstone; thin -bedded
		Menard formation.....	30-60	limestone and shale; interbedded, fossiliferous
		Waltersburg sandstone....	.....	(not recognized in area)

Locally, the alteration of Chester limestones adjacent to fault planes results in lithologic changes and faunal deformation that make age determinations difficult.

Some of the apparent differences between the Chester and Caseyville sandstones are: 1) the Lick Creek sandstone is locally conglomeratic and generally coarser than the Palestine and Degonia sandstones; and 2) the Wayside member differs from the Degonia sandstone in being locally more argillaceous, somewhat thinner-bedded, and less resistant to weathering, and commonly contains plant fossils replaced by marcasite.

Evidence of Faulting

A number of criteria were used in establishing the existence of the faults in the area. Some of these were: repetition of beds, slickensides, non-conforming dips of adjacent strata, age differences of adjacent beds, and direct observations of the fault-plane itself. The fault-plane is not commonly observed, but in the first railroad cut about one and one-half miles south of Pomona a fault-plane may be seen in the Degonia sandstone. In the W. ½ of sec. 29 the bluff is composed of Degonia sandstone whereas eastward at the same elevation on the opposite valley wall the bluff consists of Lick Creek sandstone (Fig. 3). In the S.E. ¼, sec. 32, repetition of beds can be seen in the east-flowing stream bed. Degonia strata are strongly slickensided in the N.W. ¼, sec. 33 where the formation is exposed on the hillside east of the road. Non-conforming dips of adjacent strata may be seen in the second railroad cut about two miles south of Po-

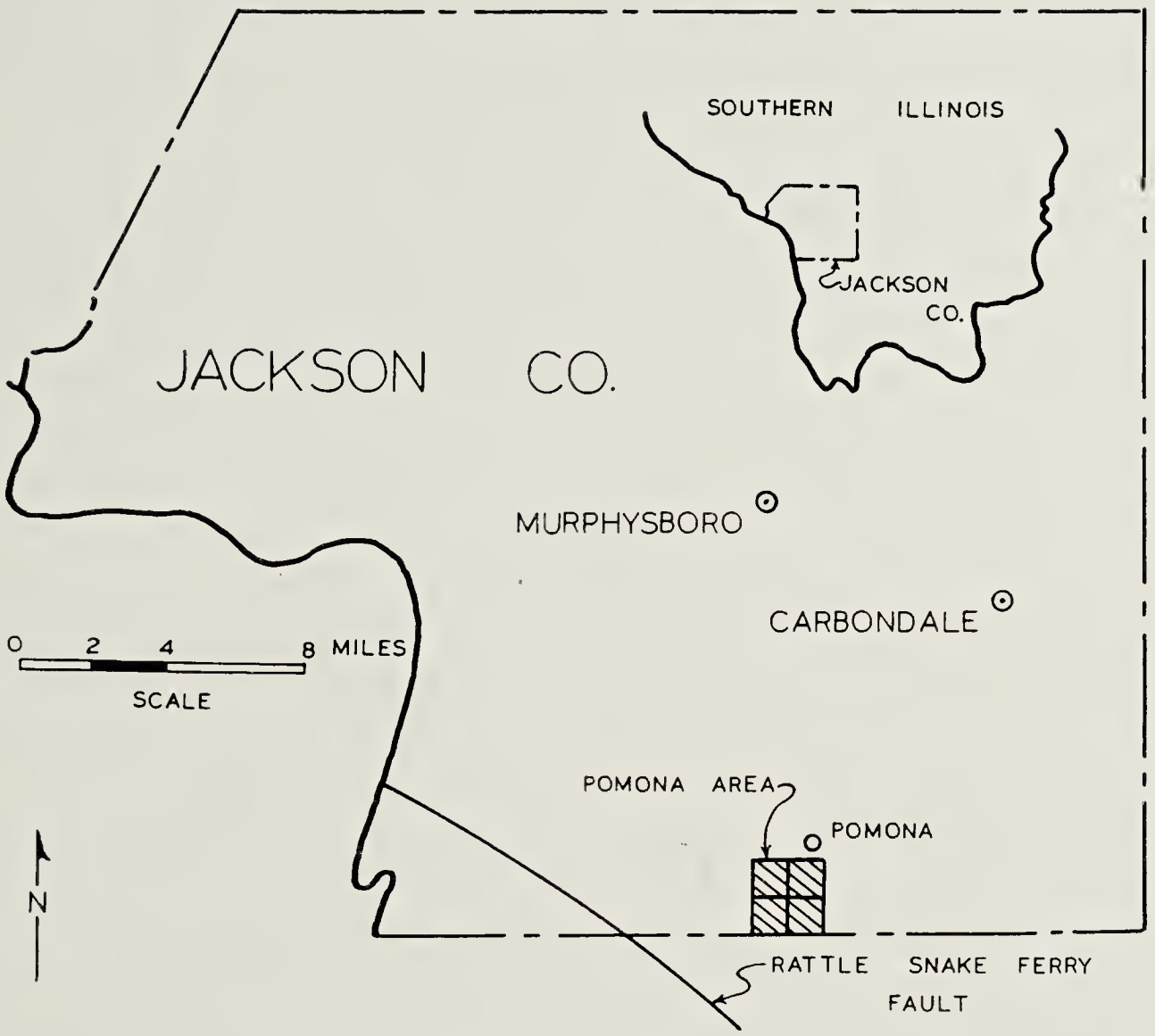

Fig. 1.—Index map of Pomona area.

mona. Here, strongly dipping Chester strata are subjacent to undisturbed Wayside shale and sandstone.

Age of Faulting

The age of some of the faulting in the Pomona Area has previously been considered as post-Chesteran—pre-Pennsylvanian (Weller and Ekblaw, 1940: 26). Although post-Chesteran—pre-Pennsylvanian faulting is important, field evidence shows that considerable post-Pennsylvanian faulting exists in the immediate vicinity of Pomona. Post-Chesteran—pre-Pennsylvanian faults are considered to be those involving Chester strata but not the overlying undisturbed Caseyville rocks.

Study of the area revealed 28 normal faults. A total of 16 faults proved to be post-Pennsylvanian in age, 8 of post-Chesteran—pre-Pennsylvanian age, and the age of 4 has not been determined (Fig. 2). Some of the faults show evidence suggesting two periods of movement: post-Chesteran—pre-Pennsylvanian and later post-Pennsylvanian displacement. Strata on the opposite sides of the fault-plane dip in different directions. In some faults these displacements appear to have been in opposite directions. The pre-Pennsylvanian faults evidently served as weakened planes along which subsequent movements occurred in post-Pennsylvanian times.

The areal pattern of the faults

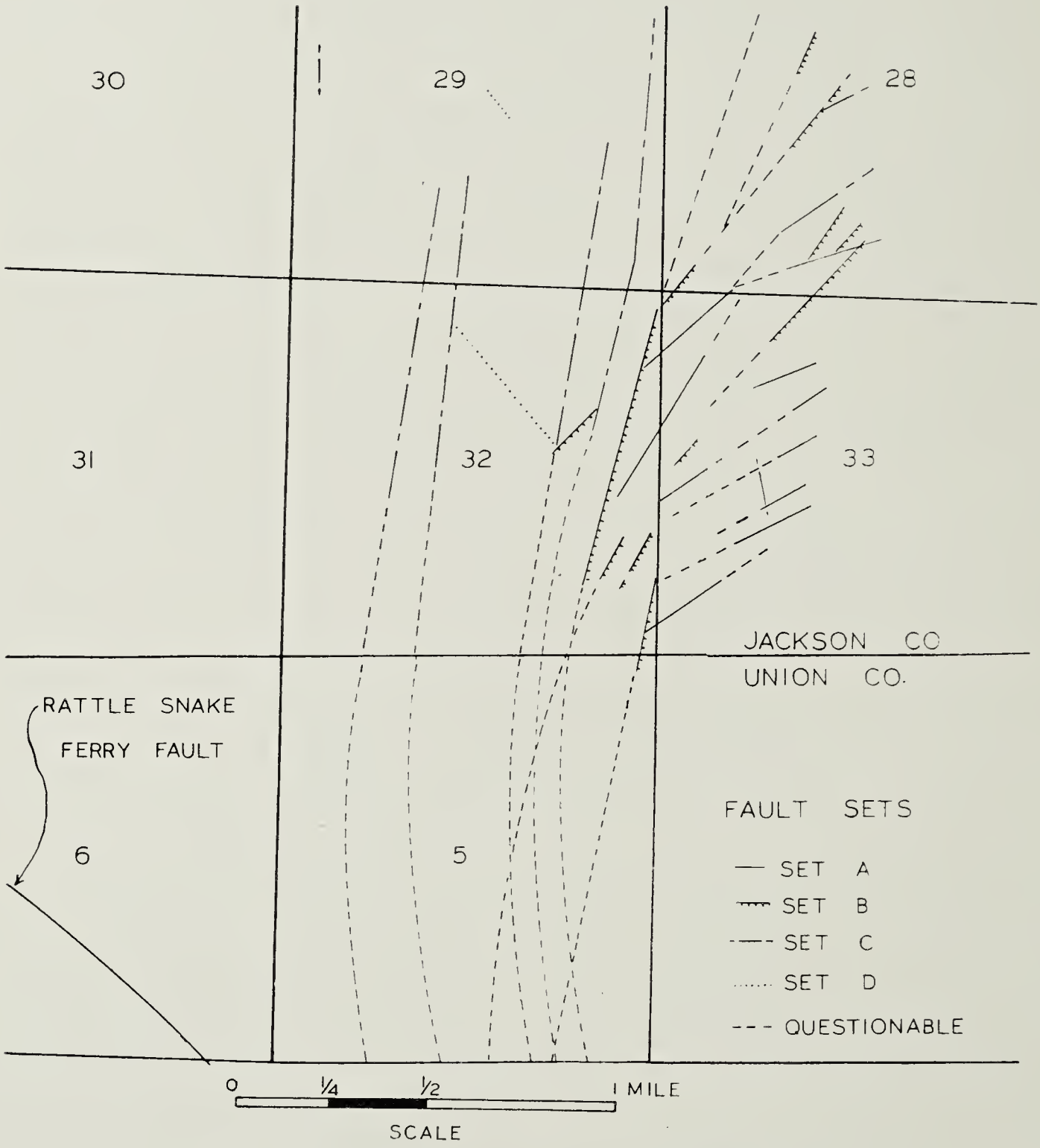

Fig. 2.—Areal pattern of faults in Pomona area.

suggests that both periods of faulting were a result of similarly oriented stresses (Fig. 2). Most of the post-Chesteran — pre-Pennsylvanian faults are open in nature, not having been sealed during or after the movement. Inasmuch as pre-Pennsylvanian faults would be planes of weakness, the pattern of the post-Pennsylvanian faults would probably not indicate proper stress orientation. Rather they would be pre-determined by the post-Chesteran—pre-Pennsylvanian structure. Thus, the areal pattern of the post-Pennsylvanian faults may not be a valid criterion for establishing post-Pennsylvanian orientation of stresses.

Fault Pattern

The faults of the area can be grouped into four sets, designated A, B, C, and D to facilitate discussion (Fig. 2). Set A consists of 10 faults which strike N.50-73°E. A total of nine faults (striking

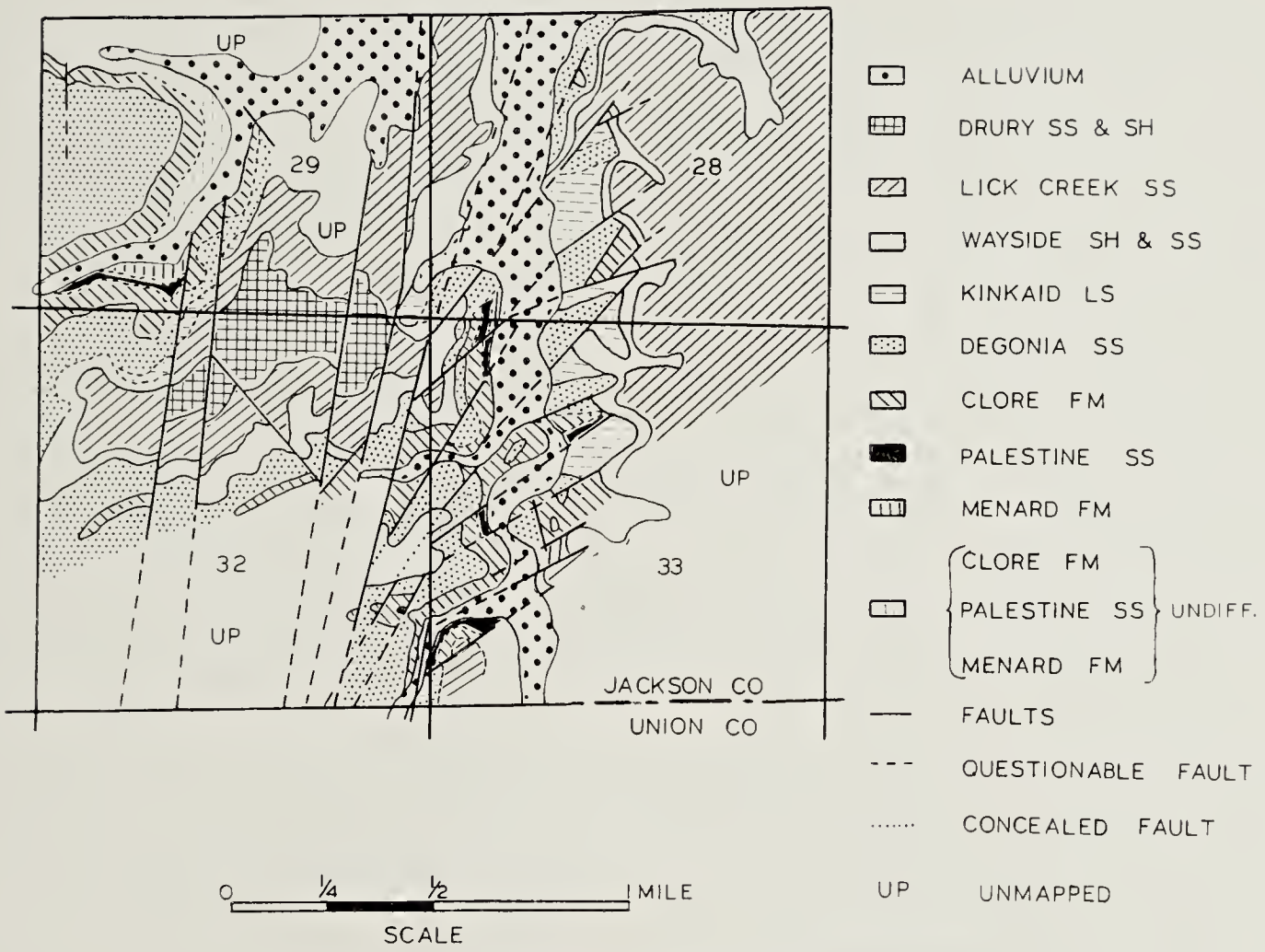

FIG. 3.—Areal geologic map of Pomona area.

N.25-43°E.) belong to set B. Set C includes seven faults which strike N.10-17°E. and two faults (striking N.39-40°W.) comprise set D.

The faults of set A have a maximum displacement of approximately 100 feet and average about 40 to 50 feet. The faults of this set are shorter than those of the other sets. The ten faults in this set have a mean direction of N.60°E. Of these ten faults, six are post-Pennsylvanian age, three pre-Pennsylvanian age, and one of an age which has not been determined.

The faults of set B have a maximum displacement of about 125 feet based on stratigraphic relationships, and average 40 to 60 feet displacement. These faults are longer than those in set A but shorter than in set C. This set has more post-Chesteran — pre-Pennsylvanian faults than any other. Of the nine faults in this set, five are of post-Chesteran—pre-Pennsylvanian age and four are post-Pennsylvanian in age. Their mean strike is N.34°E.

Set C consists of seven faults, five of which have considerable length. These are expected to be continuous southward, and they probably intersect the Rattlesnake Ferry Fault. The fault with a direction of N.17°E. is known to be continuous along its strike from the Union-Jackson County line in the SE. ½ sec. 32 northward through the town of Pomona. In this set, five of the faults are of post-Pennsylvanian age and two are of an age not determinable. The maximum displacement of these faults is approximately 100 feet; their average displacement is 50 feet. The mean strike of this set is N.50°E.

Set D comprises two faults, one with a strike N.40°W. and the other with a strike N.39°W. The fault with the greatest strike extent is of post-Pennsylvanian age. The age of the smaller fault is not determinable because it involves only Chesteran strata, and Pennsylvanian rocks are absent. The maximum displacement on each fault does not exceed 60 feet, and their minimum displacement is approximately 30 feet.

Conclusions

1. There have been at least two periods of faulting in the Pomona area—one of Post-Chesteran—pre-Pennsylvanian age, the other of post-Pennsylvanian age.

2. Post-Pennsylvanian faults are numerous in the Pomona area.

3. The areal fault pattern is not a valid criterion for establishing the orientation of the stresses which resulted in the post-Pennsylvanian fault pattern.

4. Subsequent movement along post-Chesteran —pre-Pennsylvanian faults occurred in post-Pennsylvanian time.

5. The structure of the Pomona area appears to be related to the Rattlesnake Ferry Fault. However, confirmation of this conclusion awaits additional studies in the region south of the Pomona area.

Acknowledgments

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VALLEY-SIDE EROSION IN SOUTHERN ILLINOIS

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Introduction

A steep erosional scarp and accompanying pedimented slope are common features along the sides of valleys in the upland of southern Illinois. These features are actively developing and appear to be of recent origin. The author is initiating a study of these features where accurate measurements of the rate of development can be made. It is hoped that observation of the processes at work will bring a better understanding of slope development.

The characteristics of the phenomenon are as follows:

1. Scarp extends laterally along valley-side more or less parallel to axis of valley.
2. It may "follow contour" but it rises with valley floor; it does not come down to valley floor.
3. Scarp ranges in height from few inches to 15 feet or more.
4. Where higher the feature is generally continuous for several hundred yards, whereas smaller scarps tend to be discontinuous.
5. Higher scarps are generally dissected by steep, short gullies.
6. Gullies seldom extend headward far beyond scarp front.
7. At base of scarp is a gentler erosional slope which may be likened to pediment.
8. Pediment is little dissected, but may have erosional remnants rising above its surface. Slope is nearly straight to concave upward.
9. Slope above scarp rises to upland with convex surface and is rarely dissected by gullies.
10. Scarp and pediment are generally developed in Pleistocene loess deposits. At one high scarp, pebbly glacial till underlying loess forms part of scarp and pediment below. No topographical break occurs at junction of the two materials.

The development of hillside and valley slopes has long been of major interest to geomorphologists, and a number of recent contributions have been made, of which several are cited. Papers by L. C. King (1953), C. D. Holmes (1955), and Czech's translation (1953) of Penck (1924) are particularly stimulating.

First mention of the scarp-and-pedimented-slope feature here discussed appears to have been made by Frye (1954) who described it as "pedimented tributary" valleys or "concavo-convex" gullies. He noted it particularly in the semi-arid plains of western Kansas. Hadley and Rolfe (1955) discussed a similar feature which they called seepage steps. The writer has been interested in this feature since 1950 and has observed it not only in the semi-arid plains where it is actively de-

FIG. 1.—Small scarplet or gravity slope capped by sod in left foreground. Larger continuous scarp in background.

veloping in loess, chalk, and shales, but also in loess and glacial till in the Midwest, and in chalk and sands on the Coastal Plain.

DISCUSSION

The scarplets are best seen in pastureland or abandoned fields where cultivation does not break them down. The typical pastures of southern Illinois do not have a close continuous turf and much bare space is exposed between grass tufts. During heavy rains water courses in a discontinuous sheet down the slope. Grass roots anchor the soil and serve as miniature dams which trap loosened soil particles. The water which flows over and around the grass tufts removes soil from the downslope side, producing a small scarplet from a fraction of an inch to two or three inches high and exposing the roots. Figure 1 shows an eight-inch scarp which has appeared along the hillside just below the principal convexity of the upland; it is believed to represent a coalescence at a critical line of the many miniature scarps.

To date, examination of the small scarps indicates that running water is the main degradational process. However, freezing and thawing, and wetting and drying of the soil raise and loosen particles, thus preparing them for transport, particularly at the time of heavy showers and rapid runoff. There is little evidence of mass wasting in the small scarplets. Slumps and creep were not observed. Once a free face is developed erosion proceeds rapidly.

The surface below the scarp is a wash slope of erosional origin, although it may have a veneer of sediment. It is straight to slightly concave in profile. Close to the foot of the scarp it is generally bare, but downslope it is grass-covered. Commonly a veneer of debris is found here but borings show it to be thin. At the base of higher scarps there are erosional remnants. Ridges and knobs of uneroded areas attest to the lowering of the surrounding parts.

Where the scarps have grown in size to a height of several feet a more complex denudational pattern of sheetwash, rillwash, gullying, slump, and mudslides is indicated (Fig. 2). The entire scarp tends to retreat as a unit, although it may be dissected by many parallel gullies. The gullies do not extend themselves into the upland above the scarp, apparently because the upland waters flow as a sheet on a wash slope.

At the head of the gullies and along the steep scarp, mudslides were observed. Mudslides carry large masses of material from the steep free-face to the waning slope, there to be carried off by running water (Fig. 3). Remnants of mud

FIG. 2.—Large complex valley-side scarp dissected by gullies.

outline the slide and form a curved ridge at the base. Examination of the source in the loess revealed vertical joints which were opened by wetting and drying and probably also by freezing and thawing. At times of heavy showers water from the upland runs into the joints, saturates the loess, and causes a large slab to fall outward; the mass then slides to the base of the steep slope.

It now appears that the lateral scarp increases in height by retreat into the upland. Lowering of the waning- or wash-slope may also occur as indicated by exposed roots of lespedeza. In places broad-bottomed gullies dissect this slope, invariably containing a series of retreating sod-capped falls.

Examination of the gullies in the scarp reveals that the gully walls also retreat by similar processes. The gully floor soon widens and takes on a gentle, concave cross-profile. The sides then retreat rapidly against the intergully ridge. Sheet wash and rill wash cause rapid retreat, and the gully sides develop a concave profile rising to a rounded, convex, upland surface as in a badlands area. Evidence of rapid denudation is seen in places where lespedeza roots

FIG. 3.—Mud slide on scarp face. Note source area in upper left and path with some debris extending diagonally across photograph to deposit in extreme lower right.

from the previous season are exposed. In the spring of 1957 after a series of heavy rains, the lower branches stood as much as three inches above the ground. Lateral cutting on the gully floor is not a significant process.

Summary

The development of small scarps with a pediment-like wash-slope is a common erosional feature in the Midwest. It appears to be the result of coalescence of many, small, gravity slopes at a critical line below the upland wash-slope. The scarp may grow in size to a formidable topographic feature which retreats rapidly against the upland. Where developed in loess it removes a large segment of the mantling material. A wash-slope of lesser angle develops below it.

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PHYSICS

MODERN DIELECTRIC THEORY APPLIED TO POLYMETHYLDISILOXANE MOLECULES

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INTRODUCTION

The dielectric behavior of materials has provided a method for investigating the structure of matter. Molecular structure influences the net dipole moment of the molecule. The dipole moment is the electric moment produced when the centers of gravity of the positive and negative charges of the molecule do not coincide. The presently accepted interpretation of the dielectric behavior is based upon the work of Debye and refinements by others.

Debye (1929) considered the permanent dipole moment of a polar molecule as one of the major contributors to the polarization of a dielectric in an electric field. He arrived at equation number 1, in which the symbols are: μ_o, permanent dipole moment; k, Boltzman constant; M, molecular weight; T, absolute temperature; N, Avogadro's number; d, density; ϵ, static dielectric constant; and ϵ_{oo}, optical dielectric constant. However, he assumed that neighboring molecules would not cause orientation in the absence of an external field.

Onsager (Smyth, 1955) added to Debye's work by considering the problem of the internal field of the molecule and its effect upon neighboring molecules during polarization. His equation, number 2, was derived on the assumption that molecules are spherical. The influence of neighboring molecules upon orientation was neglected.

1.

$$\mu_o = 3/2 \sqrt{\frac{kMT}{\pi N d}\left[\frac{\epsilon-1}{\epsilon+2} - \frac{\epsilon_{oo}-1}{\epsilon_{oo}+2}\right]}$$

2.

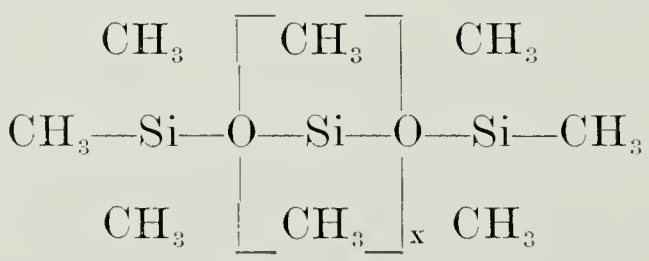
$$\mu_o = 3/2 \sqrt{\frac{kMT}{\pi N d}\,\frac{(2\epsilon+\epsilon_{oo})\ (\epsilon+2)}{3\epsilon\ (\epsilon_{oo}+2)}\left[\frac{\epsilon-1}{\epsilon+2} - \frac{\epsilon_{oo}-1}{\epsilon_{oo}+2}\right]}$$

3.

$$\sqrt{g\ \mu_o} = 3/2 \sqrt{\frac{kMT}{\pi Nd}} \left[\frac{(\epsilon - 1)\quad (2\epsilon + 1)}{9\epsilon} - \frac{\epsilon_{oo} - 1}{\epsilon_{oo} + 2} \right]$$

Kirkwood (Smyth, 1955) included the hindrance to molecular orientation in determining the dielectric polarization for polar liquids. The dipole moment by his determination is (number 3), where g is a correlation factor relating the molecular dipole moment and the moment induced by hindered rotation as a result of the field of the neighboring molecules. The correlation factor, g, is a function of the angle between dipole moments of a neighboring pair of molecules and is very difficult to determine.

The polymethyldisiloxanes (silicone oils) make excellent sample molecules to compare the dipole moments calculated from the Debye, Onsager, and Kirkwood equations. The molecules have a small permanent dipole moment caused by the Si—O—Si bond angle, and data for their physical and chemical properties are available from the published literature. The polymethyldisiloxanes are a chain-type molecule. The chemical formula (Rochow, 1951) is



where x represents the number of inner structural units.

Analysis of Data

The values of ϵ, ϵ_{oo}, d, and M are listed in Table 1 for 8 polymethyldisiloxanes at 20°C. The data for hexamethyldisiloxane (x = 0) were measured by Holland and Smyth (1955) and those for polymers x = 1, 2, 3, 4, 5, 6, and 48 were measured by Baker, Barry, and Hunter (1946); the densities were obtained from the Dow-Corning Silicone Notebook (1948). The large polymer, x = 48, was included to test the results of Debye, Onsager, and Kirkwood equations for a molecule that has a comparatively large dipole moment and thus a large internal field. Polarization produced by orientation is temperature dependent. The data discussed here were taken at 20°C; however, corresponding data are available for —20°C.

Sauer and Meade (1946) established the following empirical equation for the dipole moments of polymethyldisiloxanes:

$$\mu_o = C\sqrt{n}$$

where C is a constant and n is the number of oxygen atoms in the molecule. Holland and Smyth (1955) found the dipole moment of hexamethyldisiloxane (x = 0) to be 0.54 Debye units. This value was obtained by the benzene-solution method and was regarded as the most reliable figure available for determining C in the Sauer and Meade equation. Values from this empirical equation are included in Table 2

TABLE 1.—Dielectric Constants of Eight Polymethyldisiloxanes at 20°C.

	x=0	x=1	x=2	x=3	x=4	x=5	x=6	x=48
M	162	236	310	384	458	532	606	3714
d	.764	.823	.854	.876	.891	.902	.910	.954
ϵ	2.18	2.31	2.40	2.48	2.52	2.55	2.57	2.79
ϵ_∞	2.06	2.08	2.33	2.22	2.20	2.27	2.34	2.43

for comparison with those of Deybe, Onsager, and Kirkwood. It should be pointed out that the Kirkwood values in this table are for $\sqrt{g}\ \mu_0$.

All three equations predict an increase in the dipole moment as the size of the molecule increases, and a decrease of the moment as the temperature is lowered. The average deviation of the Debye, Onsager, and Kirkwood moments from the Sauer and Meade empirical moments are about 13, 10, and 18%, respectively. However, the average deviation for the Kirkwood equation is not too meaningful as the Kirkwood results include the $\sqrt{g}$, although g is often chosen as 1.

The correlation factor, g, is the ratio μ/μ_0, where μ is the sum of the permanent dipole moment and the moment induced as a result of hindered rotation in the spherical region surrounding the molecule. Therefore, it is reasonable to expect g to decrease as the distance separating the centers of the force fields of the neighboring molecules increases. This suggests a relation between g and the size of the molecule. We have proposed the relation

$$g = \frac{K}{\log V}$$

to supply the unknown factor in Kirkwood's equation. K is a constant and V is the molecular volume. The molecular volume is proportional to M/d, and this ratio was used in place of V to determine K. The constant K was determined from the most reliable value of μ_0, namely,

TABLE 2.—Comparison of Dipole Moments (Debye Units) Calculated from Debye, Onsager, Kirkwood, and Empirical Equations at 20°C.

	Debye μ_0	Onsager μ_0	Kirkwood $\sqrt{g}\ \mu_0$	Sauer and Meade μ_0	g	μ_0*
x=0	0.46	0.47	0.68	0.54	1.59	0.54
x=1	0.73	0.74	0.99	0.76	1.51	0.81
x=2	0.44	0.44	1.05	0.84	1.45	0.87
x=3	0.91	0.92	1.16	1.08	1.40	0.99
x=4	1.11	1.12	1.71	1.20	1.36	1.46
x=5	1.12	1.13	1.80	1.32	1.33	1.56
x=6	1.07	1.08	1.86	1.43	1.31	1.57
x=48	4.08	4.25	4.32	3.78	1.03	4.25

0.54 Debye units, and was found to be 3.70. New values of g were calculated from

$$g = \frac{3.70}{\log M/d}$$

and are listed in column 6 of Table 2. These coefficients were then applied to the Kirkwood values of Table 2 (column 4) to find μ_0*. Thus, the results (last column of Table 2) are obtained by adjustment of Kirkwood's equation as suggested by the authors. The true dipole moments are probably nearer those calculated from the empirical equation suggested by the authors, or those calculated from the Sauer and Meade equation. Additional experimental work will be required to find the correct equation.

Conclusions

From this evaluation of existing equations for dielectric properties, some conclusions regarding their application may be made.

1. The Debye equation should not be used to determine the dipole moments of pure polar liquids as the results will show considerable error. If the dipole moment is extremely small and the molecules could be isolated from each other as in a gas or in a very dilute solution, the error would be reduced as the effect of the hindered rotation would be at a minimum. However, the Onsager equation will give more accurate results as it accounts for the effect of the internal field on molecular orientation. When the Onsager equation is used for a pure polar liquid, the error is increased again because of the hindered rotation.
2. The Kirkwood equation takes into account the effects of the hindered rotation. Refinements of this equation offer the best means to account for dielectric behavior. Unless the correlation factor is known, however, the error is likely to be greater than with the Onsager equation. A modification of Kirkwood's equation has been suggested.
3. The most accurate method for determination of the molecular dipole moments at the present time entails use of the Onsager equation on measurements in dilute solutions of polar molecules in a liquid known to be non-polar. This minimizes the effect of the hindered rotation upon the orientation polarization, as the internal field for a non-polar molecule is zero. Then the dipole moments obtained from this method may be used to evaluate the correlation factor in the Kirkwood equation.

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AN INVESTIGATION OF CIGARETTE SMOKE AS AN AEROSOL WITH SPECIAL REFERENCE TO RETENTION IN LUNGS IN HUMAN SUBJECTS

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To illustrate some of the problems which are likely to be encountered in the investigation of the inhalation of aerosols, some experiments were performed using cigarette smoke (Baumberger, 1923; Greenberg, Lester and Haggard, 1952). Under suitable conditions the smoke can be generated so as to have reproducible characteristics. Since cigarette smoke contains a number of chemical constituents which can be measured in small amounts, some experiments were performed on human subjects to determine the retention in the lung of a few of these constituents of the smoke under certain types of breathing patterns.

Methods

A burning cigarette was placed in a holder 6 cm. long and with a volume of about 5 cc. The cigarette and holder were then enclosed in a small container to which a tank supplied 0.4 liters of air per minute (Fig. 1). The system was so arranged that all of the air which left the chamber passed through the cigarette and holder. Smoke generated in this manner was quite concentrated so that particles increased in size due to coalescence. To prevent this type of change in particle size from continuing, the smoke upon leaving the holder was directed into a mixing tube where the particles were continuously diluted with air at the rate of 35 liters per minute or higher. The particle-size distribution of cigarette smoke generated in the above manner was found to be very reproducible.

The importance of rapid sampling in the case of fairly concentrated aerosols can be illustrated by the following example. If the air flow through the cigarette is increased to several liters per minute, the interval of time from the formation of the smoke to the moment of sampling can be varied from long to very short time intervals. The mass median diameters (M.M.D.'s) of the smoke particles corresponding to the following time intervals—0.05, 1, 11, 30 seconds—were, respectively, 0.3, 0.65, 1.4, and 1.6 microns in a typical trial.

One brand of cigarettes was used to obtain most of the results, but seven other brands were used for comparisons. The smoke was collected by impaction as described below, about two-thirds of each cigarette being used. The smoke particles, when examined microscopically, appeared to be clear droplets unless they remained airborne too long. A collected sample appeared as a

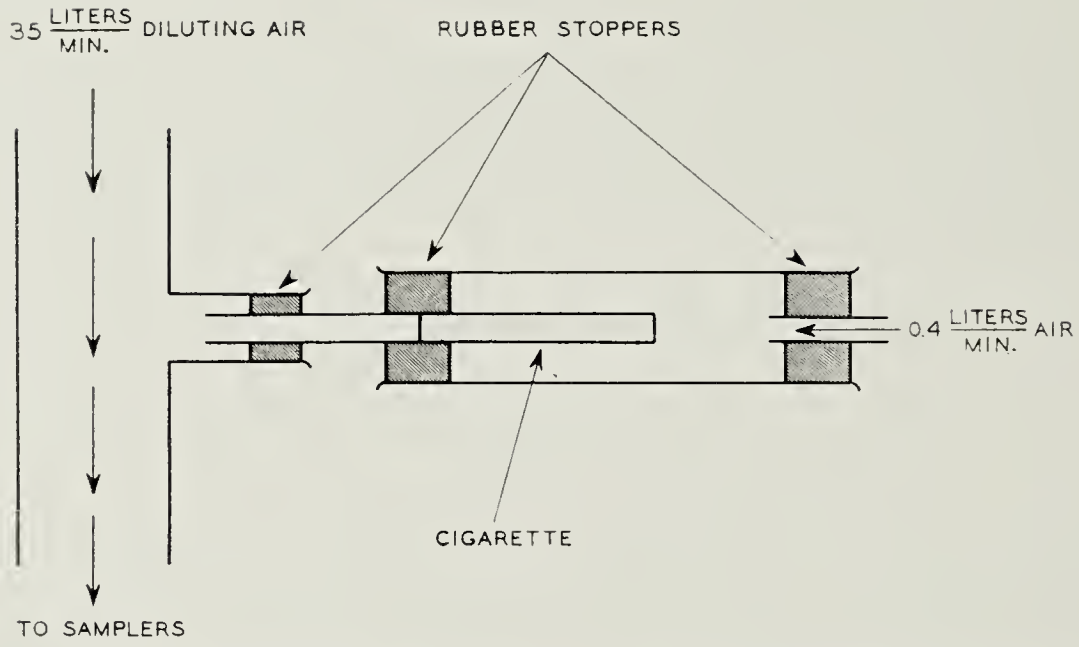

FIG. 1.—Apparatus used to produce constant characteristics in cigarette smoke.

brown viscous liquid. The following types of analyses were made on the samples.

Color.—To make a color analysis (First, Moschella, Silverman, and Berly, 1951) a sample of smoke was washed with absolute alcohol from the collecting device into a graduated test tube. The resulting mixture was then adjusted to a final volume of 10 cc. This final mixture, when stirred thoroughly, had a uniformly clear, yellow color which was read on a Klett colorimeter using a 420 mμ filter. Such color readings were found to be linear with concentration over a wide range of optical densities. The presence of small amounts of undissolved particles in the mixture did not appreciably alter the optical density.

Phenol.—If the alcohol is evaporated from a small aliquot of an alcoholic extract of smoke, the resulting material develops a blue color characteristic of the presence of phenol, using the Folin and Ciocalteau (1927) method of analysis for phenol. Since the Folin and Ciocalteau reagent is not specific for phenol we will simply call the combined substances detected by this reagent "Phenol". The mixtures were somewhat turbid. However, because of the wavelength used and because the turbidity was correlated with the blue color developed, the effect of the turbidity on the calculated percentages of retention was almost negligible as indicated by a comparison of values obtained on clear (centrifuged) and turbid samples. Hence, in most of the experiments the effect of turbidity was ignored.

259 mu.—The "259 mu" values were found by taking an aliquot of the sample in water, removing the alcohol, and acidifying with HCl to a pH of 1. The solution was then read at 259 millimicrons on a Beckman Model DU spectrophotometer. It was found that many other substances interfered with the nicotine values (Griffith and Jeffery, 1948) as obtained from readings at 236, 259, and 282 millimicrons; consequently, the values obtained at 259 were in reality rather independent of the amount of nicotine. The readings at the peak for nicotine, *i.e.*, at 259 millimicrons were not much different from the average of the other

TABLE 1.—Particle-size Distribution of Cigarette Smoke.

	Color (420 mμ)	Phenol	259 mμ	Nicotine
Cloud fraction (diameter)	Standard cloud			
3	1.1 ± 0.5	1.8 ± 0.7	2.0 ± 0.4	1.7 ± 0.7
4 (1.4 μ)	51.0 ± 2.0	55.0 ± 2.0	50.0 ± 1.0	53.0 ± 3.0
5_1 (0.76 μ)	26.0 ± 2.0	25.0 ± 3.0	27.0 ± 2.0	25.0 ± 4.0
5_{2s} (0.3 μ)	15.0 ± 1.0	12.0 ± 1.0	13.0 ± 1.0	15.0 ± 1.0
GW	6.4 ± 1.5	5.4 ± 0.5	8.0 ± 1.0	5.0 ± 1.0
M.M.D.	0.96	1.02	0.96	1.00

EXHALED SMOKE
(8-second cycle, 18 liters per minute)

	No condensation	With condensation	No condensation	With condensation	No condensation	With condensation	
3	2.0 ± 0.5	7.5	2.3 ± 0.2	9	4.0 ± 0.3	11	
4	39.0 ± 2.0	60.0	40.0 ± 2.0	54	40.0 ± 1.0	51	
5_1	28.0 ± 2.0	18.0	28.0 ± 3.0	21	25.0 ± 1.0	20	
5_{2s}	25.0 ± 2.0	12.0	24.0 ± 2.0	12	23.0 ± 3.0	14	
GW	6.0 ± 2.0	2.0	6.0 ± 2.0	3	8.0 ± 1.0	4	
M.M.D.	0.74	1.27	0.76	1.23	0.78	1.20	

two readings. Thus, although these values could not be considered as being due primarily to nicotine, they were useful to illustrate the fate of certain constituents when inhaled by human subjects.

Nicotine.—Since distillation resulted in so great a dilution, and since small amounts of materials were often involved, a colorimetric method sensitive to small amounts of nicotine (10-100 micrograms) was used (Landahl and Tracewell, unpubl.).

Particle-size distribution. — The relative amounts of a constituent in droplets of different sizes were obtained by means of glass impacting devices (May, 1945; Sonkin, 1946) through which the air passed in series. The first section used, section 3, collected the largest particles (fraction 3). Section 3 consisted of a right angle bend (over a distance of about 3 cm.) of a tube of inner diameter 4.0 mm. Fraction 4 was collected in section 4, in impinger with orifice 2.0 mm. jetting upon a surface 4 mm. away (Landahl and Black, 1947, Fig. 1). Fractions 5_1 and 5_{2s} were collected on similar impingers of orifice diameter 1.58 mm., the later having two 200-mesh, 0.002″-wire screens at the surface of impaction 4 mm. from the orifice. These impingers were from a laboratory model cascade impactor designed to be constructed easily from standard glass (or brass) tubing, the sections being joined, for example, by standard taper joints. Sections 1 and 2, which were not used in these experiments, were made respectively from 16 and 8 mm. inside diameter tubing, the right angle bends being fairly smooth, and without noticeable constrictions.

The sections of this impacting device were calibrated when possible by microscopic observations and by the instrument of May (1945). For very small values the sizes were estimated by producing larger particles containing a relatively volatile solvent which was then removed by evaporation. The mass median diameter of each section was found to depend somewhat on the amounts of materials in the sections preceding it. The following information enables one to take this into account. When the amount of material collected on sections 1, 2, 3, together with one half of that on 4 was 85% of the total, the M. M. D. for 4 was 2.0 microns. Similarly when 85% was on or above the midpoint of 2 or 3, respectively, the corresponding M. M. D.'s were about 13 and 5.8; the values corresponding to 5, 5_1, and 5_{2s} being 0.9, 0.9, and 0.25. Section 5 was an impinger of 1.40 mm. diameter orifice which could be used in place of 5_1 and 5_{2s} without changing the flow rate. When 50% of the mass of the particles was on or above the mid-point of section 1, its M.M.D. was estimated to be about 27 microns. Similarly for section 2, etc. the M.M.D.'s were, respectively 10, 4.5, 1.6, 0.6, 0.65, and 0.15 microns, the last value being an indirect estimate. When a criterion of 15% on or above the midpoint of a given section was used the M.M.D.'s were as follows: For 1, etc., the values were, respectively, 16, 7, 3.5, 1.3, 0.3, 0.4, and < 0.1 microns. By interpolating from these values, the M.M.D.'s of various cloud fractions can be estimated. If impingers are used instead of bent tubes for 1, 2,

and 3, the orifice diameter should be about 15% larger than the tube diameters to obtain about the same results, the distance from orifice to plate being equal to the orifice diameter.

In series with the above devices and nearest to the pump (such capacity that pressure at pump was much less than one-half atmosphere), was an orifice about 2 mm. diameter which jetted onto 5 layers of glass wool cloth (fraction GW), about 4 mm. from the orifice. The fibers of the glass were 20 microns in diameter. The discs of glass wool cloth were held in a filter holder (Landahl and Black, 1947, Fig. 1, F) so that all the air passed through the glass wool filter at near the velocity of sound. Some experiments indicated that even particles much less than 0.1 microns are removed to a rather large extent by this glass wool impinger-filter, provided the pressure at the glass wool is sufficiently low. The flow rate, 18 liters per minute, was not appreciably changed by this last impinger.

Some observations indicated that several percent of the nicotine were lost by evaporation. However, the effects on the percentages retained are probably small since the exhaled and control samples were treated as much alike as possible.

Experimental Results

Particle-size distribution.—The results of experiments on particle size are given in Table 1. The results did not indicate any significant difference between any one brand and the average of all the brands of cigarettes, including one long cigarette and one with a built-in filter. The distribution using color as an index was the same as that for phenol, 259 mμ, and nicotine, except possibly the first and last fractions. These latter were unreliable, since they constituted such a small fraction of the total mass. As the material in the last fraction was spread over a relatively large surface, evaporation of nicotine could be responsible for its being somewhat less.

Smoke particles upon being inhaled and then exhaled into warmed collectors were found to have a slightly smaller average diameter than they had before being inhaled. Since the retention is about 50% under these conditions (see below) it is seen that the particles in cloud fraction 4 are retained more than those of 5_1 and 5_{2s}. On the other hand, the exhaled particles may have increased in size due to acquisition of moisture (cloud fraction 3). Under condensation (*e.g.*, collectors not warmed, about 25°C) one might expect to find considerable differences in the change in size for different sized particles if the particles were not fairly uniform in their composition. Since this does not occur, this again suggests similarity in composition of small and large particles for smoke produced under a given set of conditions.

A single impinger 5_{2s} collects all the material that falls above it as well as practically all that falls on it when in series with the others. Since this represents most of the material, the experiments to measure total retention in lungs were carried out using only such impingers with the orifice size being 1.40 mm. for 18 liters per minute and 2.54 mm. for 60 liters per minute.

TABLE 2.—Relative Concentration of Exhaled Smoke (per cent).[1]

Exhaled fraction	18 liters per minute		60 liters per minute			
	Color	Phenol	Color	Phenol	259 mu	Nicotine
	4-second cycle, 450 cc. tidal air		4-second cycle, 1500 cc. tidal air			
1	78	..	84	77	77	30
2	73	..	73	61	60	15
3	64	..	58	46	47	8
4	52	..	38	16	35	3
Totals	67	..	63	50	55	14
	8-second cycle, 900 cc. tidal air		8-second cycle, 3000 cc. tidal air			
1	80	72	79	..	..	18
2	51	34	54	..	..	4
3	38	28	36	..	..	0.6
4	27	18	22	..	..	0.5
Totals	49	38	48	39	34	6

[1] Relative concentration is defined as ratio of average concentration of substance in given portion of expired air to that of inspired air.

Brand variation. — One subject was used to measure the total per cent retention of smoke at the eight-second respiratory cycle, for various brands of cigarettes. The inspiratory and expiratory rates were both 18 liters per minute. All respiratory cycles used were divided into equal inhalation and exhalation periods of three-eighths of the cycle time, separated by pauses of one-eighth of the cycle time. From three to five trials were made with each brand with the following percentages retained: 49 ± 2, 54 ± 1, 49 ± 1, 51 ± 1, 53 ± 2, 52 ± 1, 52 ± 3, 51 ± 1. This gives an average value of $51.0\pm1.3\%$.

Of the 28 comparisons by pairs, only one pair showed a moderately significant difference. This is not unexpected in this many comparisons even if there were actually no differences. Furthermore, the correlation between the M. M. D.'s and the retentions of the materials from the various brands was not found to be significant.

Retention for various respiratory patterns.—Two subjects were used to measure the percentage retention for various patterns of respiration. From three to six trials were made on each subject for total retention on brand A. One subject was used in the experiments in which the expired air was fractionated into four equal serial fractions (exhaled fraction 1, 2, 3, 4 of Table 2, Landahl, Tracewell, and Lassen, 1951). Two to four trials were made in this situa-

tion. The results of these experiments are given in Table 2.

It may be seen from Table 2 that phenol, 259 mu, and especially nicotine are retained to a greater extent than color. This can be accounted for by the removal of these materials as vapor. Furthermore, the color is removed to a somewhat greater extent than triphenylphosphate particles (Landahl, Tracewell and Lassen, 1951, 1953) of corresponding size. Whether or not this can be accounted for by the absorption of moisture or by vaporization remains to be determined. We also note that the total retentions for color are less sensitive to changes in respiratory pattern than in the case of triphenylphosphate droplets. In the case of nicotine, the distillation from the particles to the walls of the respiratory passages appears to be as important as or more important than the removal of particles by settling, impaction, and diffusion (Landahl, 1950).

In addition to the experiments summarized in Table 2, one experiment was carried out at 18 liters per minute using a 12-second cycle and 1350 cc. tidal air. Only color was measured. The relative concentrations for the exhaled fractions 1 to 4 were, respectively, 73, 45, 33, and 22%. The total was 43%.

Summary

Experiments have been carried out to measure the particle-size distribution of cigarette smoke, generated in a fixed manner, as measured by various components. The results indicate that, for smoke generated under a given condition, the chemical composition of the droplets making up the smoke may be rather independent of the droplet size. Measurements carried out on exhaled smoke tended to confirm this latter generalization. Human subjects were used to measure retention under various respiratory patterns in which a few components were analyzed. The various components analyzed were found to be retained to different extents, demonstrating the importance of the volatility of the component. This may be illustrated by a comparison of the percentages retained for phenol and nicotine. A breathing pattern having a 4-second cycle and an inspiratory flow rate of 60 liters per minute gave, respectively, 50% and 86% retentions for phenol and for nicotine. Other conditions showed a similar result. Measurements were also made of the amounts of different components in various fractions of the expired smoke.

Acknowledgment

This investigation was carried out at the University of Chicago Toxicity Laboratory under a contract with the U. S. Atomic Energy Commission. The authors wish to thank Scott Bartky for the design and construction of the electronic apparatus which determined the temporal pattern for the respiratory cycles and controlled the samplers. The authors are indebted to Warren Lassen and to A. Hasegawa for technical assistance in some parts of this work and to Dr. K. P. DuBois for reading and discussing the manuscript.

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SCIENCE EDUCATION, PSYCHOLOGY AND SOCIAL SCIENCE

SUBJECT MATTER TRENDS IN SCIENCE IN ELEMENTARY SCHOOLS AS SHOWN BY COURSES OF STUDY

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Introduction

There has been considerable written about the shortage of scientists, engineers, and science teachers. Today we live in an age of science. The place to initiate an interest in science for today's youngster is not the high school, but the elementary school. It is the opinion of the author that programs in science in the elementary schools taught by teachers who like science and youngsters will produce enough future science teachers and scientists to provide the needs of future generations. However, the purpose of teaching science in the elementary school is not only to produce science teachers, engineers, or scientists.

Science is so interesting that, when taught by a teacher who is aware of this and who can stimulate and develop the interest of his pupils, it will serve to provide a path which may lead to careers for many of the pupils. However, if science in the elementary school is taught by a teacher who has a fear of it, then many pupils will not be exposed and many may acquire the teacher's fear and dislike.

The increasing awareness of the importance of science in our lives has caused people to wonder about the science curriculum in the elementary school (Dubins, 1957:23). Linus Pauling (1951:52), Chairman of the Chemistry Department at the California Institute of Technology, has stated, "Through experience we have learned that the way to teach mathematics is from the kindergarten up in all grades . . . the time has now come for the study of science to be made a part of the curriculum in every grade, in every level through high school and college . . . only in this way can we train citizens for life in the modern world. Only in this way can we develop a citizenry able to solve the great social and political problems confronting us in this world."

What is the content of the elementary curriculum in science? Has it changed during the last 35 years? What would be a good way to study the science content of the elementary school curriculum for this period? There are different ways of arriving at answers to these questions. One of the best is by means of the course of study which is a guide prepared

by school personnel as an aid for teaching in a given subject or area of study.

Since 1922, periodic analyses of courses of study in science in the elementary grades have been made. Those found in the literature were investigated and the data pertaining to the content of the courses of study in science in the elementary school were carefully studied. The author analyzed courses of study in science in elementary schools prepared from 1940-1952, scattered over the United States. It was necessary wherever possible to regroup the data to have a basis for comparison for the different periods in which the courses of study were prepared.

Elementary Science Courses of Study Previous to 1927

Reinoehl (1922) made one of the earliest, most detailed, and most important analyses of science content in courses of study in the elementary school. His study covers most of the material published from 1910 through 1920 on rural elementary schools. As none of the courses of study included the term elementary science, Reinoehl (1922:32, 88) classified geography, hygiene, physical education, and nature study as categories of elementary science. He listed topics appearing in 80% or more, 60-80%, and 40-60% of the courses of study.

Abstracting from his study the topics which would be taught in an elementary classroom in science today, one finds weather records, soils, air pressure, moisture in the air, winds, clouds, fog, iron mining, day and night, seasons, sun, moon, stars from the earth sciences. These are the only topics from the physical sciences. In nature study and hygiene, which are most closely related to the biological sciences, there are numerous topics. Indeed, these two categories make up most of the science program in the course of study.

Two years after Reinoehl's investigation, Hillman's (1924) research became available. He investigated the science curriculum of the elementary school from a geographic sample of courses of study for 1921 to 1922. Hillman categorized the topics of the science program into plant studies, animal studies, and physical and chemical topics and made a frequency study of them by grade levels in which they were taught.

His overall analysis showed that there was little change in the make-up of the science curriculum from grade one through grade five as three-fourths of the topics were related to animal and plant life and one-fourth to physical and chemical matters. In grade six the emphasis shifted with physical and chemical topics constituting almost half of the topics.

The topics classified by Hillman (1924:23) into physical and chemical with the greatest frequency were as follows: weather observations, snow, soil, frost, wind, clouds, ice, ventilation, thermometer, sun, heating homes, moon, dew, sun position, water, direction, stars and compass. No more than the top 19 have been listed because of the paucity of occurrence of the others. Many of the top 19 items are confined to the primary grades, and several to the intermediate grades.

In order of frequency the top 20 topics related to animal and plant

life were as follows (Hillman, 1924: 18, 19): bird identification, tree recognition, identification of common flowers, seed dispersal, seed germination, seeds, butterflies, dogs, autumn leaves, bird migration, identifying weeds, horses, habits of birds, caterpillars, cats, fruits, gardening, cows, rabbits, and bees.

The Period of Transition

Courses of study in science in the elementary school written between 1930 and 1940 were analyzed for science content by Herbert Bruner and his associates (Bruner, 1941). Unfortunately the content of the primary grades was not investigated.

A reclassification of Bruner's data into topics dealing with plants and animals and those dealing with physical sciences revealed the following:

1. Grade 4 had 56.4% biological versus 43.5% physical science topics.
2. Grade 5 had 59.5% biological versus 40.5% physical science topics.
3. Grade 6 had 31.4% biological versus 68.6% physical science topics.

Those topics dealing with physical science in Bruner's list included: current electricity, earth measurements, light, heat, sound, machines, magnetism and electricity, matter, oxygen and oxidation, scientific methods, and steam. Many of them did not appear in the courses of study written before 1927. Those physical science topics which appeared in the pre-1927 courses of study had a greater frequency of occurrence in the 1930 to 1940 period. By comparing in the intermediate grades the courses of study in the pre-1927 period and the 1930 to 1940 period, it can be readily seen that the number and percentage of physical science topics greatly increased, especially at the sixth grade level.

Alice Gilbert (1943:769 - 773) studied the content of 30 elementary science courses. Her findings were similar to those of Bruner. She found that the fields of science had a greater representation in elementary science in 1943 than in 1924. Her 20 topics with the greatest frequency occurrence rank as follows: protection of birds by man, importance of the sun, ways birds are valuable to man, migration of birds, uses of water, life history of the frog, relation of time units to movement of the earth, life history of the honey bee, factors necessary for plant growth, locations of constellations, movements of the moon, movements of the sun, formation of rocks, life history of the ant, changes in the earth's surface, life history of the butterfly, identification of common garden flowers, green plants make their own food, scattering of seeds, and habits of domesticated animals.

Undoubtedly one of the reasons for the increase of physical science content in the elementary school curriculum was the work of Gerald Craig now Professor Emeritus at Columbia University. In 1927 he developed a course of study in science for the Horace Mann Elementary School which was affiliated with Columbia University. He was a pioneer in breaking away from the bonds of the nature study centered science curriculum of the elementary school of that time. His work had

wide influence and "the results . . . were soon reflected in school curricula throughout the country" (Underhill, 1941:220).

Analyses of Recent Courses in Science in Elementary Schools

Dubins (1953) analyzed courses in science in the elementary school, prepared from 1940 through 1952. The science content for each grade through six was carefully investigated, using as the main instrument a Subject Matter Content Guide. This was devised to provide a numerical, consistent, yet simple means of recording data from which conclusions concerning the subject matter of courses of study in elementary science could be drawn. It is a reference, listing the material being taught in science in the elementary school, the grades in which the material is being taught, and the number of school systems whose courses of study were investigated teaching the subject matter.

The framework is as follows:

Areas and Sub-areas in Elementary School Science

Area 1. *The earth*:—Sub-areas: A, air; B, water; C, composition of earth; D, forces changing earth's surface; E, history of earth; F, weather.

Area 2. *The heavens*:—Sub-areas: A, relation of earth to moon and sun; B, solar system; C, stars and galaxies; D, comets, meteors, and meteorites.

Area 3. *Energy*:—Sub-areas: A, atomic and molecular forces; B, chemical energy; C, magnetism; D, electricity; E, gravity; F, heat; G, light; H, sound.

Area 4. *Living things*:—Sub-areas: A, classification; B, distribution of plants and animals; C, needs; D, how plants and animals obtain food; E, interdependence, dependence, and independence; F, adaptation; G, reproduction; H, growth; I, improvement; J, response to stimuli.

Area 5. *Man's control of his environment*: — Sub-areas: A, man's control over living things; B, man's use of earth products; C, man's use of energy; D, conservation; E, health; F, safety.

Each sub-area is made up of topics, both major and minor, with minor topics occasionally being broken down into other minor topics. The frequency of occurrence of each topic by grade level was determined.

In order to have data which would serve as a basis of comparison with data obtained in analyses of previous courses of study, the frequencies of occurrence of the topics listed were totaled under physical sciences and biological sciences. It is realized that a clear-cut differentiation is not possible. However, as was done in previous studies, topics pertaining to plants and animals were placed in one group and all other topics in another group.

The number of topics dealing with the physical sciences in each grade exceeded the number dealing with the biological sciences. The difference was as much as 10% for each grade up to and including four. For grades five and six there were 17% more topics in the physical sciences.

The emphasis in rank order (Dubins, 1953:466) given the major areas was as follows: earth, 1; living things, 2; man's control of his en-

TABLE 1.—Comparison of Percentages of Topics Dealing with Physical and Biological Sciences in Elementary School Science Courses.

Grade	Biological			Physical		
	1920, Hillman	1930-40, Bruner	1940-52, Dubins	1920, Hillman	1930-40, Bruner	1940-52, Dubins
1	76.0	....	44.2	24.0	....	55.8
2	76.0	....	45.2	24.0	....	54.8
3	73.5	....	44.8	26.5	....	55.2
4	78.2	56.5	45.4	21.8	43.5	54.6
5	70.0	59.5	41.4	30.0	40.5	58.6
6	53.0	31.4	41.5	47.0	68.6	58.5
Totals	72.8	53.6	42.9	27.2	46.4	57.1

vironment, 3; energy, 4; and the heavens, 5.

The emphasis in rank order given the sub-areas (Dubins, 1953:467) was as follows:

1. Weather
2. Adaptation
3. Relation of earth to moon and sun
4. Water
5. Health
6. Composition of earth
7. Growth
8. Air
9. Heat
10. Man's use of energy
11. Conservation
12. Man's control over living things
13. Electricity
14. Light
15. Forces changing earth's surface
16. Interdependence, dependence, independence
17. Classification of living things
18. How plants and animals obtain food
19. Man's use of earth products
20. Stars and galaxies
21. Magnetism
22. Reproduction
23. Needs of living things
24. Safety
25. Solar system
26. Sound
27. Distribution of living things
28. History of earth
29. Atomic and molecular forces
30. Response to stimuli
31. Improvement of living things
32. Gravity
33. Chemical energy
34. Comets, meteors, and meteorites

Dubins (1953:468) found that the 25 most popular major topics in order of frequency of occurrence in the courses of study in elementary science, published from 1940 to 1952, were as follows: sun, moon, role of water in health, heat (weather), weather instruments, wind, sun's role in weather, stars, condensation, plants need water, measurements of heat, properties of water, earth relative to moon and sun, uses of air, constellations, types of precipitation, uses of water, uses of electricity, machines, uses of heat, plants need sunlight, animals' means of protection against enemies, erosion of earth's surface, plant structure, and oxygen.

Most of the studies investigated indicated that there was little agreement among the courses of study as far as the subject matter was concerned. Dubins (1953:465) found that less than 4% of the 476 major topics reoccurred in over half of the 163 grade-courses of study. Slightly less than one sixth of the major topics reoccurred in from 25 to 49% of the grade-courses of study. There is much confusion as to what subject

matter should be taught. However, it is encouraging to find that today over the United States more and more physical science is being taught in the elementary grades, and that the study of animals and plants no longer dominates the science program.

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CHALLENGE ACCEPTED!

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Within the past decade, educators and educational systems have been targets for many critical shafts. An encouraging outcome of these open attacks was the diligence with which school systems began to re-examine and re-evaluate their methods and procedures which the general public had called into question. This almost universal dissatisfaction challenged the faculty and administrators of Saint Xavier College to initiate a self study of the aims and organization of their own liberal arts college. Although a program of self-criticism had been in practice since 1935, a vigorous stimulus to this movement came, in 1953, in the form of a grant from the Fund for the Advancement of Education.

Saint Xavier College has for its goal the liberal education of the Christian person. It is dedicated to the belief that the liberal arts should be taught to all students in our American schools. Concisely stated by one of our staff, "In a democratic society every young person should have the opportunity to achieve some mastery of the liberal arts, including the reluctant and unmotivated, not because the liberal arts are college preparatory, but because they are the rightful heritage of every human being."

Introduction

Members of the combined faculties of Saint Xavier College and the Albertus Magnus Lyceum of Natural Science cooperated in developing and implementing our plan. The various committees appointed to this endeavour soon became cognizant of the fact that a revision of college courses would be futile if the present high-school courses were pursued. Likewise, a re-examination and re-ordering of the secondary program demanded a further revision at the grade-school level. So, as the work progressed it became more and more evident that, to establish a model system of liberal education, the present system—from grade school through college—would have to be reconstructed.

Fortunately the faculty of Saint Xavier College was in a better position to undertake such a wholesale revision of an educational system than were some other educators faced with a similar desire. Saint Xavier College is conducted by the Sisters of Mercy of the Chicago Province, a religious order whose members also teach in approximately 50 grade schools and 7 high schools in the Chicago area. These provide an ideal proving ground for the educational theories resulting from the self-study program.

This summary will attempt to give the general ideas currently being developed in this experimental curriculum and will include some detail regarding the science program. The development of the natural science program was greatly aided by a grant from the Carnegie Corporation of New York.

Schooling at the elementary level confines itself to pre-scientific studies and the pre-liberal arts. Natural science, precisely as a science or habit of mind distinct from other habits, can only be taught at the college level. The acquisition of this habit requires extensive factual knowledge, considerable exercise in logic and mathematics, and a maturity of mind that cannot be expected at the lower levels. Consequently, the experiential and experimental knowledge of nature gained at the elementary level is the prerequisite for the science itself. Moreover, the liberal arts must fulfill two conditions—they must produce an order within the mind by means of mental relations and they must be useful instruments for the sciences. At the elementary level the student is expected to achieve a certain mastery of the linguistic arts and the fine arts, as well as the mathematical skills. All these deal rather with external signs than with the ordering of internal concepts; consequently, these disciplines are called pre-liberal arts. The liberal arts proper, being intermediate between elementary and higher education, are reserved for the secondary-school student to pursue, And, although the college is primarily concerned with imparting knowledge in the fields of science, humanities, and wisdom, the college freshmen and sophomores continue their mastery of the liberal arts and general education subjects begun in the high school.

The science program in our school system is constructed on the premise that it is from natural science that the social sciences and theology derive their natural basic concepts, since both the social sciences and wisdom depend materially on sense experience. Natural science is the study of the world of nature and of ourselves as part of that world, knowledge of which is derived through our senses. The liberal arts are the basic tools needed by the student to equip him for a formal study of science.

Elementary-School Program

Therefore, science in the strict sense is not taught in the elementary school, but at this level the child is led to develop an observational knowledge of nature in order to accumulate a rich background of factual experience to which he can revert later in his educational life when he is searching for theoretical explanations of scientific phenomena.

Nature study, even at the primary level, is not haphazard, but orderly and systematic in its development, being integrated closely with religion and social studies. For example, in first grade, or what is designated as the first level of achievement, the aim of nature study is to bring the child to a realization of the order and beauty of the world around him. He observes the sky, the heavenly bodies, the families of plants and animals. His personal

experiences are enriched with the Bible stories of creation, nature stories, poems, and the making of drawings and plastic replicas of objects he has observed in nature. Meanwhile, in social studies, the child is learning about the family unit, the need of tolerance and mutual love in daily life.

As his experiences increase, he becomes aware that the sun and moon follow an orderly pattern, obeying certain physical laws; the plants and animals, too, submit to laws governing the cycle of the seasons; concurrently, the child is learning the necessity of authority and obedience in his social life. The child that is made to realize that the plant and animal friends of the classroom, home, or field must be given proper care, if they are to survive, will more readily accept the principle taught in his social science lesson that personal sacrifice is often necessary to promote the common good.

From the achievement level corresponding to about fourth grade through the upper grades, nature study becomes autonomous but is still closely correlated with social studies. The child at the intermediate level augments his store of aesthetic facts about nature, while in his social studies he is becoming acquainted with those worshippers of beauty, the people of the Mediterranean world. He learns how much the culture, science, and art of the Greek world contributed to his own cultural heritage.

A study of modern conservation methods in a science lesson ties up nicely with the Medieval period of history, wherein the effects of monasticism on medieval agrarian economy may be seen. The age of chivalry, guilds, and monastic schools bequeathed many social, cultural, and economic benefits, not the least of which were methods of cultivation inaugurated in the reclamation movement of the time.

At the upper level of the child's elementary schooling, the development of modern technology and inventions (discovered largely by experimental methods) is considered and evaluated. Simultaneously, in social science, he is following the development of the modern world, the American way of life.

Secondary-School Program

The high-school freshmen and the sophomores, in a science course entitled "Man in His World," expand the basic facts about nature gleaned in the elementary school. The content of the course is relatively the same as the traditional general science and biology courses of the secondary school. However, the subject matter has been reordered to make man the central topic of this study. In first-year high school the structures and functions of the human systems are studied in a logical sequence and the general science matter related to each system is studied conjointly. Beginning with the skeletal system, since its structure accounts for man's unique upright position, the student learns the names and locations of the common bones, and the general functions of this system. The general science topic correlated with this subject is good posture. Since the bones fulfill their function of movement with the aid of the muscles, the muscular system is next studied. The bone-

muscle interrelationship illustrates several simple principles of mechanics. Usually a student is fascinated by the idea that he uses a simple machine every time he nods his head, stands on tiptoe, plays handball, rolls his eyes, or takes a swinging stride. Consequently, that part of general science dealing with the simple concepts of work and types of simple machines, *i.e.*, the three classes of levers, pulleys, and the pendulum, comprises the correlation here.

Seeking for the source of the energy required for the body to do the work of muscular movement, the pupil progresses to a study of the digestive system. Correlated with the study of the structure and function of this system is the study of nutrition, oral hygiene, and an introduction to elementary concepts of food chemistry — elements, compounds, mixtures, physical and chemical changes, oxidation, etc.

The problem next raised is how the food reaches all parts of the body; hence, the circulatory system is investigated. The marvelous pumping organ of the body arouses the students' curiosity regarding the principle behind simple hydraulic and suction pumps which are then studied.

Interrelated with the consideration of the respiratory system, which furnishes the oxygen transported by the blood, is a study of the composition and physical properties of air, and the sequential topics of weather, and climate. The instruments studied in conjunction with weather call into use mathematical skills necessary to convert readings on the thermometer and barometer.

The student becomes aware of a simplified concept of filtration when he studies the parts of the excretory system of man; here, too, hygienic habits of regular elimination and body cleanliness are emphasized.

A search for the system responsible for coordinating all the systems of the body reveals the work of the nervous system. As the special sense organs are studied, there follow the physical sciences related to each. For example, a study of light follows the study of the eye. This in turn leads to the source of light, the solar system; hence the simple facts of astronomy are acquired. The structure and function of the ear are not separated from the physical phenomena of sound. The student learns, too, that man has internal as well as external senses and is introduced to some elementary principles of psychology at which time he considers the value of developing a sound theory of mental hygiene.

The course concludes with the reproductive system and topics in related fields of cytology, genetics, and anthropology. Contrary to traditional courses in which the student is introduced to biology through a study of the cell, in this science course, the student begins his investigation with the macroscopic unit, man. The adolescent is primarily interested in himself and needs little motivation to study himself in detail; moreover, he is more familiar with man than with the microscopic units of which man is composed. The cell and mitotic cell division are treated at the end of the course in conjunction with the study of the reproductive system. By this time the student should be sufficient-

ly mature to take microscopic study seriously.

Upon completing his study of man, the student is aware that man can control himself and that man is in a position to control parts of his environment. Therefore, the second-year course begins with a study of how man can control disease and preserve his good health. The anatomical and physiological background acquired in the freshman course makes intelligible the units on disease and medicine usually found in general science texts. This topic also provides a good transition between the first- and second-year courses. The greater part of the subject matter for the second year follows the traditional study of the botanical and zoological facts found in most second-year science books. It includes, in addition to this, the general science topics not covered in the first year. After learning about plants and animals in man's environment, the student proceeds to observe how man influences his environment. The study of conservation of soil, forest, wildlife, and water shows how man rationally uses his natural resources. The topic of how man controls fire to preserve forest and wildlife leads to a consideration of how man controls energy—mechanical, chemical, and nuclear. Consequently, the types of simple mechanical machines not covered in the first-year courses are studied at this point; here, too, the problem of the atom and hydrogen bomb is discussed.

With this rich background of factual knowledge accumulated through elementary school and the first two years in high school, the high-school junior begins to learn the techniques of natural science. He now applies to controlled laboratory investigations of problems in physics and chemistry the mathematical skills he has acquired and, in addition, learns the fundamental laws of scientific investigation. Aiding his understanding of the dialectical methods used in the empirical sciences will be his knowledge of logic gained in the courses in critical analysis. It is our firm belief that logic lives when it is transplanted to special situations while it is still "warm."

College Program

All students in our college are required to take a two-year course in natural science. The first semester treats of the basic concepts and principles underlying natural science, *i.e.*, nature, causality, motion, and its concomitants of time, space, place, and the continuum. The student is now interested not only in the fact, but the reason for the fact, and uses his knowledge of logic and general philosophical principles to guide experimentation and analyze results; in other words, he learns the value of strict scientific demonstration.

In the second semester of his freshman year, application of the general principles learned in the fundamental course is made in the field of the physical sciences. The principal concepts of Newtonian physics are examined and analyzed in a study of Newtonian mechanics and gravitational motion. Other topics include the structure of matter, light, sound, and the periodicity of the elements. The accumulation of facts is kept at a minimum, being

confined to those necessary to a proper understanding of the concepts under discussion.

A course entitled the "Principles and Methods of Biology" comprises the third-semester of work in natural science. Again, concepts and principles are stressed and the fundamental ideas learned in a general way in the introductory course are applied to particular cases in the field of biology. The activities and organization common to all organisms are investigated in order to be able to define and classify living things. A typical lower plant and a higher plant, as well as an invertebrate and a vertebrate animal, are then studied in some detail. In seeking explanations for the biological phenomena which a study of these forms reveals, a causal analysis is used that goes beyond that of many modern scientists who frame their concepts within the limits of Newtonian physics and overlook, or ignore, causality.

The fourth-semester course completes the study of living things by proceeding to a knowledge of man's appetitive and intellective powers. It is entitled "Principles and Methods of Psychology" and stresses the important principles of that field.

Laboratory exercises and techniques proper to the sciences pursued in each semester are assigned to give empirical knowledge in the four areas mentioned.

This two-year course required of our students is designed to satisfy the needs of the collegian desiring a general education. Moreover, it is so planned as to utilize the liberal arts; and through reading assignments of classical experiments in each of the three fields covered, it exemplifies how the leading contributors in the field have used the liberal arts. It is our hope that this course will motivate students to elect a major in the field of science.

After completing this basic two-year sequence in the natural sciences, the college student is in a position to advance to the specialized study of science, fortified with a view of nature that has depth, and possessing a methodology that should produce pentrating thinkers in science, not merely technologists.

The plan as outlined here is still in the early experimental stages of development, and years may pass before results can be properly evaluated. Nonetheless, the faculty of Saint Xavier College feels that it is moving in the right direction—away from the accumulation of facts, and toward an understanding of the philosophical principles underlying the observed facts. The teachers cannot promise themselves success, but the explanation of triumph is all in the first syllable—*try*.

ZOOLOGY

THE OS CLITORIDIS IN THE BADGER, *Taxidea taxus*

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The os clitoridis is a bony or cartilaginous structure, found in many female mammals; it is thought to be homologous to the os penis of the male. The os clitoridis has been reported from at least a few animals belonging to most orders of mammals, but its presence or absence in the various species is poorly known. Among the fissiped Carnivora, it may occur in many species, but has been recorded from only a few. These are summarized by Layne (1954) and are as follows:

Ursidae: *Ursus,* bear; *Thalarctos,* polar bear.

Procyonidae: *Procyon lotor,* raccoon; *Nasua narica,* coati mundi.

Mustelidae: *Martes,* marten or fisher; *Lutra,* river otter; *Putorius,* polecat or ferret; *Mustela,* weasel.

Viverridae: *Cryptoprocta,* fossa.

Canidae: *Urocyon cinereoargenteus,* gray fox.

Felidae: *Panthera,* lion etc.

The os clitoridis has apparently not been reported in the American badger, *Taxidea taxus.* In March, 1956, while examining the carcass of a freshly skinned badger, we discovered this bone. The animal (Univ. Ill., Mus. Nat. Hist., No. 14369) was an adult, pregnant female taken three miles north and one mile west of St. Joseph, Champaign County, Illinois. This is in the east-central part of the state. Again in November, 1956, we obtained another female badger (Univ. Ill., Mus. Nat. Hist., No. 15179) from the same general vicinity, this time from six and one-half miles north, one mile west of St. Joseph. The os clitoridis was similar in shape and configuration to the first.

The vulva containing the clitoris was macerated in a 2% solution of potassium hydroxide, stained with alizarin red, and cleared in glycerin.

The position of the os clitoridis with relation to the urogenital sinus and clitoris is shown in Figure 1. It did not seem possible to us that the bone could be extruded externally as Rinker (1944:92) found was possible in the case of the raccoon, *Procyon lotor.* The bone itself is broad, flat, and curved. It is not unlike a rib, in miniature, twisted and more curved, rounded at the proximal end and with a "head" or knob at the distal end (Fig. 2). From the distal knob which is slightly off center, the shaft gradually broadens and flattens. Near its middle, the shaft twists nearly 90 degrees, and the proximal end is not only bent in another plane but also curves dorsad. This twisting of the shaft of the os clitoridis is somewhat comparable to the twisting in the distal third of the

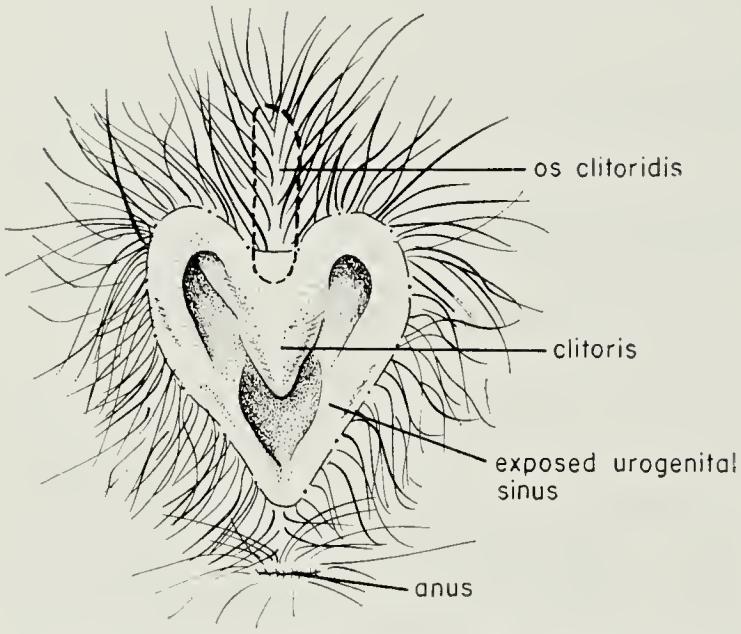

FIG. 1.—Ventral view with vulva dissected to show urogenital sinus, clitoris, and position of underlying os clitoridis. (No. 15179).

os penis in the badger. In a general way, the terminal parts of these bones in the female and male badger are similar.

The overall length of the os clitoridis of specimen No. 14369 is 13.3 mm.; of No. 15179, 11.2 mm. The greatest width of the shaft of No. 14369 is 2.0 mm.

Although the os clitoridis of the two specimens differs in size and somewhat in shape, to us these individual differences do not seem to be much greater than those in the os penis of badgers.

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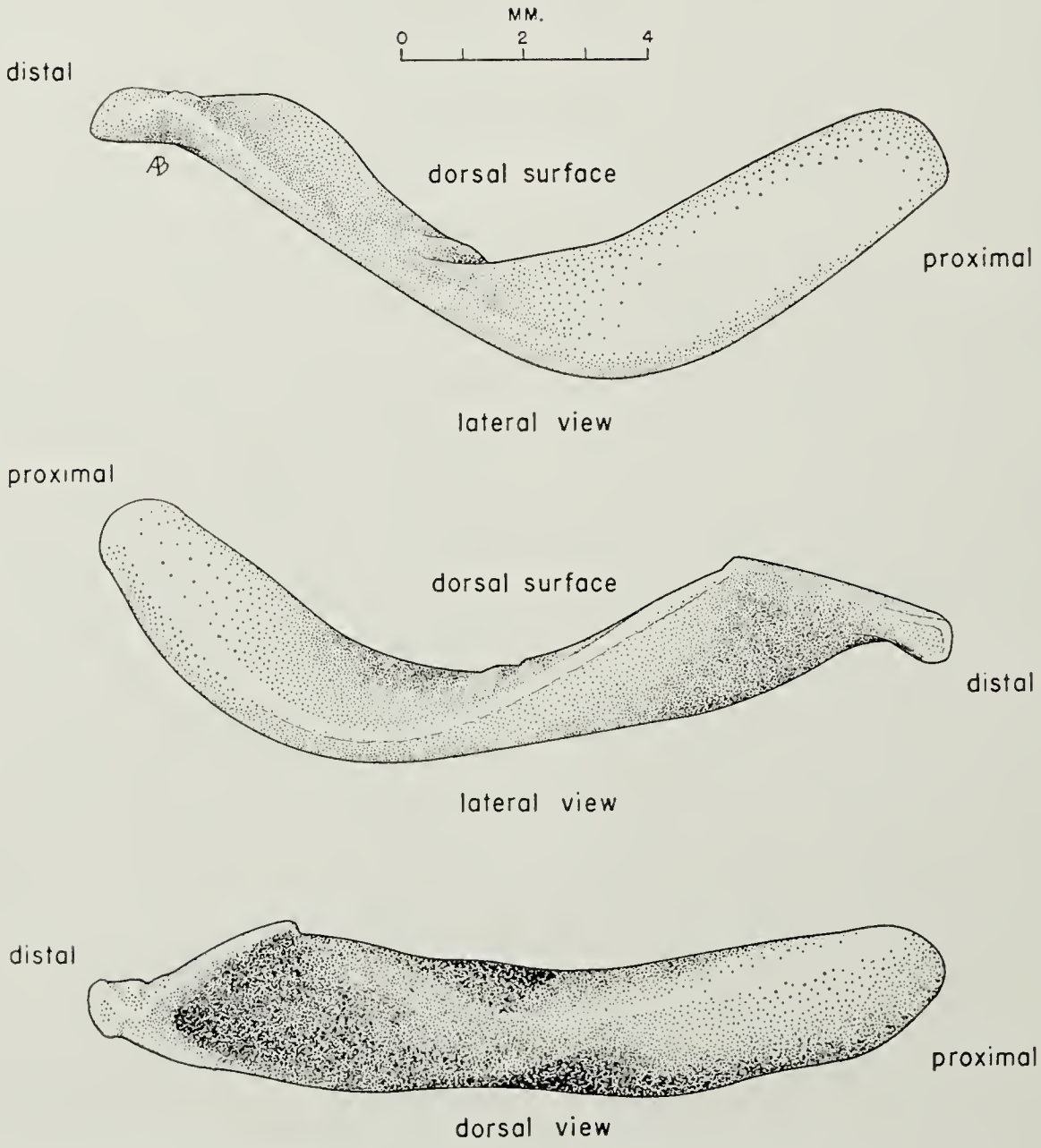

FIG. 2.—Lateral views of os clitoridis (No. 14369); dorsal view (No. 15179).

VERTEBRATE REMAINS FROM THE CAHOKIA SITE, ILLINOIS

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Introduction

The work of Moorehead (1929) dealing with the historical setting, general description, village areas, mounds, and possible cultural affiliations of this Middle Mississippi Site is the most detailed and comprehensive report yet published on Cahokia. This site, probably the largest of its kind in North America, is located immediately east of the East St. Louis area and is generally thought to have been occupied from about 1,200 to 1,550 A.D. Dr. Frank C. Baker, former Director, Museum of Natural History, University of Illinois, Urbana, was vitally interested in faunal remains found in Indian sites, and he made significant contributions to the field of ethnozoology or archaeozoology in Illinois through identification and interpretation of midden materials (Baker, 1923, 1930, 1931, 1936). The last major contribution by Baker (1941) comprised an up-to-date account of species identified from midden refuse at Cahokia and several other major sites and areas in Illinois.

From September through December, 1956, Mr. Gregory Perino excavated approximately one acre of the village site east of Monk's Mound and a section of the west slope of Mound No. 34. Mr. Perino gave the immense quantity of animal remains he uncovered to the author for identification and use of the resulting data. Although the shell, most of which was marine (Parmalee 1958a), was rather poorly preserved, the majority of the animal bones were in excellent condition.

Animal remains found in Indian refuse pits and debris from kitchen middens can provide a wealth of information concerning the prehistoric environment and ecology of an area as well as the former abundance and distribution of species. The quantity of faunal material removed by Mr. Perino at Cahokia was the largest for any one site in Illinois, with the greatest number of animal species being represented. All classes of vertebrates were encountered, but the birds and mammals were better represented, both numerically and in number of species. Nearly 9,800 bones were identified; included were a minimum of 10 species of fish, one species of frog, five species of turtles, 58 species of birds and 19 species of mammals (Table 1).

Acknowledgments

I would like to express my appreciation to Mr. Gregory Perino for the opportunity to utilize the animal remains recovered at Cahokia, and to Dr. Alexander Wetmore, U. S. National Museum, Washington, for

his kindess in verifying some identifications and in determining certain bird bones.

Discussion of Species

Fishes:—Remains of fishes were relatively common but, in relation to the total number of bones from this sample, not so numerous as might be expected. Remains of catfish and catostomids (buffalo and suckers) were found most commonly, thus indicating that these fishes were preferred or that they were more readily obtainable by the Indian. It appears that little use was made of other "rough" fishes such as gar and bowfin. In contrast, bones and/or scales of these latter species were fairly abundant in the midden material from the Modoc Rock Shelter (Fowler, Winters, and Parmalee, 1956), an archaic site in southwestern Illinois. The larger size of individual fishes and the greater number of remains of a more limited number of species that could, under present-day standards, be considered preferred (*i.e.,* catfish, buffalo, freshwater drum), indicate a possible change in fishing habits from the primitive Archaic to the more advanced Hopewell and Middle Mississippi cultures.

Fish bones from the Modoc Site were primarily of small individuals and of species (suckers, bullheads, gar, bowfin) that commonly inhabit quiet, backwater sloughs, ponds and marshes. Judging from the remains of some unusually large drum, buffalo and catfish (*Ictalurus,* especially) found in Hopewell (*i. e.* Snyder Site, Calhoun Co.; Clear Lake Site, Tazewell Co.) and Middle Mississippi sites (Cahokia), these later people utilized the main channels of the rivers and deeper waters, and possibly had developed better fishing techniques in the form of traps, nets and seines.

A single, drilled tooth of the white shark was found and it, as in the instance of numerous marine mollusks, in all probability represents a trade item from the Gulf or South Atlantic coast.

Amphibians and reptiles:—Several long bones of a large frog, probably the bullfrog, *Rana catesbeiana,* were identified. At the time the Cahokia Site was occupied, the area was apparently a maze of lakes, marshes and small streams, so that the presence of frog bones could be, and probably is, the natural result of their expected presence in the area.

Remains of turtles were uncommon in proportion to the total number of bones and were evidently little used by the Indians occupying this section of Cahokia. The common aquatic species (*Pseudemys, Chrysemys, Graptemys*) were the most numerous, and several shell sections and fragments showed evidence of having been drilled or worked, being used possibly as spoons or other utensils. With the exception of the shark, all species of fishes and the turtles identified from this sample of midden material still occur in Illinois and within the general proximity of Cahokia.

Birds:—The number of bones and the variety of avian species present one of the most interesting aspects dealing with the ecological interpretation of Cahokia based on faunal re-

mains. Of the 2,944 identified bird bones, 2189 (representing at least 20 species) or 74.4% are those of ducks, geese and swans. This does not include approximately 250 additional duck bones (primarily *Anas* and *Aythya*) which, because of their fragmentary condition or questionable characteristics, were not specifically identified. Such a high percentage of waterfowl is noteworthy (and typical of most sites in Illinois) in that it points to a preference (coupled with the factors of availability and abundance) for these birds by the Indian, thus serving as an indication of prehistoric ecological conditions. Approximately 40% of the bird remains were waterfowl species and in the case of ducks and geese, the most common species then (mallard, teal and scaup plus species of *Branta* and *Chen*) are still common migrants along the Mississippi River.

As noted earlier, this area was covered with numerous lakes, ponds, marshes, and small streams and, being in close association with the Mississippi River Flyway, provided excellent habitat for waterfowl. Birds such as sandhill crane, great blue heron, pied-billed grebe, American egret, American bittern, and various shore birds which are associated with an aquatic environment, were probably common but seldom if ever used as food. Remains of the coot were numerous, thus indicating its use as a food while turkey and prairie chicken bones comprised slightly over 10% of the total.

Of particular interest is the large number of bones of trumpeter swans, a species that became extinct in Illinois about 1912. Although the flesh of this bird was probably eaten, the Indians also prized it for the bones, primarily the wing bones and especially the humerus. The ends of thirty-five humeri showed signs of having been cut off and several cut sections of the bone were also found. Several cut ends of the radius, ulna, femur, tibiotarsus, and carpometacarpus were also observed; apparently the bones were cut into sections and utilized as beads.

Several bones of the Canada goose and the turkey, cut in a similar fashion, were also encountered. The cut proximal end of a right humerus of the white pelican, a species now considered a rare migrant in Illinois, was recovered and is of interest since it is the second archaeozoological record (first: tarsometatarsal fragment, Snyders Site, Calhoun Co., 1955, Parmalee, 1958b) of this bird in Illinois. Other species of particular note are the long-billed curlew, sandhill crane, passenger pigeon, swallow-tailed kite, raven, Carolina paroquet, and ivory-billed woodpecker, (Parmalee, *op. cit.*). In contrast to sites in Ohio (Goslin, 1955) and a site in southern Missouri (Stephen Williams, pers. comm.), remains of the formerly abundant passenger pigeon are relatively rare in Illinois. Thus far the greatest number (approximately 40) have been encountered at the Modoc Site with only one or a few bones reported from other sites throughout the state.

The record of the swallow-tailed kite is noteworthy in that it is again the first archaeozoological record of this southern species in Illinois; there are published records of seven specimens having been collected in

TABLE 1.—Animals Identified from Cahokia Village Site, Madison Co., Illinois, 1956.

Species	No. remains
FISHES	
Bullhead, *Ictalurus*	60
Buffalo and suckers, Catostomidae	38
Bigmouth buffalo, *Ictiobus cyprinellus*	31
Channel catfish, *Ictalurus lacustris*, and/or blue catfish, *I. furcatus*	25
Freshwater drum, *Aplodinotus grunniens*	24
Catfish spp.	15
Smallmouth buffalo, *Ictiobus bubalus*, and/or black buffalo, *I. niger*	13
Gar, *Lepisosteus*	12
Longnose gar, *L. osseus*	9
Flathead catfish, *Pilodictis olivaris*	4
Bowfin, *Amia calva*	3
Bass, *Micropterus*	1
White shark, *Carcharodon carcharias*	1
AMPHIBIANS	
Frog, *Rana*	7
REPTILES	
Pond te rapin, *Pseudemys scripta*; painted turtle, *Chrysemys picta*; and/or map turtle, *Graptemys geographica*	57
Pond terrapin, *Pseudemys scripta*	12
Snapping turtle, *Chelydra serpentina*	9
Map turtle, *Graptemys geographica*	2
Soft-shelled turtle, *Trionyx*	1
BIRDS	
Mallard, *Anas platyrhynchos*. Some possibly black duck, *Anas rubripes*	480
Trumpeter swan, *Olor buccinator*	376
Turkey, *Meleagris gallopavo*	261
Snow goose, *Chen hyperborea* and/or blue goose, *C. caerulescens*	257
Canada goose, *Branta canadensis*	236
Green-winged teal, *Anas carolinensis*	199
Prairie chicken, *Tympanuchus cupido*	143
Lesser scaup, *Aythya affinis*	120
Sandhill crane, *Grus canadensis*	99
Blue-winged teal, *Anas discors*	78
Goose spp.	67
Swan, *Olor*	56
Common coot, *Fulica americana*	52
Wood duck, *Aix sponsa*	45
Teal, *Anas* spp.	40
Canvasback, *Aythya valisineria*	36
Bufflehead, *Bucephala albeola*	31
Bald eagle, *Haliaeetus leucocephalus*	29
Ruddy duck, *Oxyura jamaicensis*	27
American widgeon, *Mareca americana*	26
Pintail, *Anas acuta*	26
Duck, *Anas* spp. mallard; pintail; black; gadwall group	23
Lesser scaup; ring-necked duck, *Aythya* spp.	22
Double-crested cormorant, *Phalacrocorax auritus*	22
Lesser yellowlegs, *Totanus flavipes*	15
Ring-necked duck, *Aythya collaris*	15
American merganser, *Mergus merganser*	12
Merganser, *Mergus*	12

TABLE 1.—Continued.

Species	No. remains
Barred owl, *Strix varia*	11
Gadwall, *Anas strepera*	10
Sandpipers and/or plovers, Charadriiformes	10
Whistling swan, *Olor columbianus*	8
Cooper's hawk, *Accipiter cooperii*	8
Pied-billed grebe, *Podilymbus podiceps*	7
Hooded merganser, *Lophodytes cucullatus*	7
Redhead, *Aythya americanus*	6
Common egret, *Casmerodius albus*	6
Passenger pigeon, *Ectopistes migratorius*	6
Common grackle, *Quiscalus quiscula*	5
Shoveler, *Spatula clypeata*	5
Red-tailed hawk, *Buteo jamaicensis*	5
Rough-legged hawk, *Buteo lagopus*	4
Common loon, *Gavia immer*	3
Red-shouldered hawk, *Buteo lineatus*	3
Great blue heron, *Ardea herodias*	3
Raven, *Corvus corax*	3
Golden eagle, *Aquila chrysaetos*	3
Carolina paroquet, *Conuropsis carolinensis*	3
Killdeer, *Charadrius vociferus*	2
Gull, *Larus* sp. Probably ring-billed gull, *L. delawarensis*	2
King rail, *Rallus elegans*	2
American bittern, *Botaurus lentiginosus*	2
American golden plover, *Pluvialus dominica*	2
Long-billed curlew, *Numenius americanus*	2
Swallow-tailed kite, *Elanoides forficatus*	2
Upland plover, *Bartramia longicauda*	1
Crow, *Corvus brachyrhynchos*	1
Barn owl, *Tyto alba*	1
Ivory-billed woodpecker, *Campephilus principalis*	1
Sparrow hawk, *Falco sparverius*	1
Great horned owl, *Bubo virginianus*	1
Screech owl, *Otus asio*	1
White pelican, *Pelecanus erythrorhynchos*	1
Greater yellowlegs, *Totanus melanoleucus*	1
MAMMALS	
Whitetail deer, *Odocoileus virginianus*	6,005
Fox squirrel, *Sciurus niger*	222
Gray squirrel, *Sciurus carolinensis*	133
Domestic dog, *Canis familiaris*, and *Canis* sp.	58
Rice rat, *Oryzomys palustris*	54
Squirrel, *Sciurus* spp.	50
Pocket gopher, *Geomys bursarius*	35
Cottontail, *Sylvilagus floridanus*	34
Raccoon, *Procyon lotor*	24
Muskrat, *Ondatra zibethica*	18
Elk, *Cervus canadensis*	10
Beaver, *Castor canadensis*	6
Woodchuck, *Marmota monax*	2
Fisher, *Martes pennanti*	2
Franklin ground squirrel, *Citellus franklini*	1
Mink, *Mustela vison*	1
Gray fox, *Urocyon cinereoargenteus*	1
Striped skunk, *Mephitis mephitis*	1
Gray wolf, *Canis lupus*	1
Coyote, *Canis latrans*	1

northeastern Illinois (1895 and 1905) and one sight record in DeWitt County (Smith and Parmalee, 1955). The above data, coupled with records of the swallow-tailed kite and the Mississippi kite, *Ictinia misisippiensis* from Ohio (Goslin, 1955) and Illinois (Parmalee, 1958b) sites indicate a greater abundance of these southern raptores as visitants and migrants (or nesters?) during early times in the more northern latitudes.

Remains of the sandhill crane, now a rare migrant in Illinois, were fairly common at Cahokia. In the summer of 1953, Mr. Perino found nine bills of the Carolina paroquet in a single refuse pit near the same location where he recovered a tarsometatarsus and two ulnae of this species in 1956. The occurrence of the paroquet, as well as the ivory-billed woodpecker, at Cahokia is noteworthy since neither have been previously recorded from Illinois Indian sites. It is somewhat surprising, particularly in the instance of the Carolina paroquet, that remains of this showy bird have not been encountered more often and in greater numbers in sites throughout this region.

Remains of several species of hawks and owls were recovered and all, except the kite, occur within the area today. A bill, carpometacarpus and tarsometatarsus of the golden eagle were found, as were a tarsometatarsus, 2 phalanges, and 26 carpometacarpals of the bald eagle. The large number of carpometacarpals, the wing bone supporting the primary flight feathers, points to the possibility that the Indian used the wing tips of the eagle for decoration or ceremony. In this connection, of the 42 identified hawk and owl remains, 38 (90%) were wing bones. Probably numerous species of birds such as hawks, owls, eagles and cranes were taken for their plumage rather than for food.

Mammals: — The whitetail deer comprised approximately two-thirds of the total number of all identified bones, thus indicating its former abundance and desirability as a staple food by the Indian. A large percentage of the deer jaws were worn smooth at the tip, showing signs of having been used as a tool or utensil. Examples are illustrated by Perino (1957). Elk were apparently uncommon in the Cahokia area or for some reason little used, as remains are few. Two distal ends of a metacarpal (or metatarsal) were found; they had been cut off and they exhibited additional cut marks or "decorations".

The quantity of remains of fox and gray squirrels again points to preference and selective hunting, as do the numbers of bones of trumpeter swans and prairie chickens. Domestic dogs were apparently common during the time the site was occupied; of interest is a cut and marked jaw of a coyote and two femurs of *C. latrans or C. familiaris* that had been cut off, one at the proximal and one at the distal end. The palatine section of a gray wolf skull was found in a refuse pit and bore signs of having been cut; possibly it had been carried or worn as a trophy since remains of the larger carnivores (*i.e.* bear, puma, bobcat, wolf), particularly skulls, jaws and teeth, were evidently held in high esteem.

The presence of the rice rat at Ca-

hokia attests to the marshy grasslands that must have existed in this region. This rodent now occurs in such areas only in southern Illinois, although in prehistoric times the range of the rice rat extended northward to Peoria county, as evidenced by remains found at the Kingston Site (Baker, 1936). The complete dentary and anterior half of the skull of a fisher were found in the village midden refuse (Parmalee, 1958c); the presence of this mustelid in west-central Illinois represents a 200-mile southern extension of its known range in the state. Bones of a variety of other mammals were identified, but it is evident that the whitetail deer was utilized to a far greater extent than any other single species.

Summary

1. In 1956, Mr. Gregory Perino excavated approximately one acre of the Cahokia village, a large Middle Mississippi site in western Madison Co., Illinois. Approximately 9,800 bones, representing all classes of vertebrates, were identified by the author.

2. The whitetail deer and several species of waterfowl, especially geese (*Branta* and *Chen*), mallard, teal, and lesser scaup, constituted a major portion of the vertebrate remains. Bones of a large variety of birds and mammals and, to a lesser extent, fish and turtles, were identified (Table 1); most still occur within the general vicinity of Cahokia.

3. Bones of several extinct and rare Illinois species (passenger pigeon, Carolina paroquet, ivory-billed woodpecker, long-billed curlew, raven, swallow-tailed kite, and fisher) were found, their presence at Cahokia representing new archaeozoological records, extensions of ranges and indications of the prehistoric ecology of the area. The presence of the rice rat and a variety of waterfowl and birds associated with an aquatic environment indicated the former existence of numerous lakes, marshes, and streams. The abundance of remains of prairie chickens pointed to the proximity of former areas of extensive grassland and prairie.

4. The numerous cut bones of several species (trumpeter swan, Canada goose, turkey, and whitetail deer) showed a secondary use of animals in the manufacture of ornaments, tools, and utensils from bone. In the instance of the bald eagle and possibly others, it appeared that some animals taken by the occupants of Cahokia were collected for their plumage, hides, and bones rather than as food.

5. The quantity and variety of animal remains from the Cahokia Site served as an excellent indicator of animal abundance and distribution in relation to ecological conditions in that region during prehistoric times.

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MAINTENANCE OF GONADS OF FROG LARVAE IN ORGAN CULTURES

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INTRODUCTION

A number of media have been used for the cultivation *in vitro* of amphibian tissues and organs (Wilde, 1948; Preston, 1949; Boss, 1954; Foote and Foote, 1957). Such media usually contain blood serum or plasma and embryo extracts from mammalian or avian sources. These culture media are adequate for the maintenance of tissues and organs, and they usually provide the proper nutritional elements for growth and proliferation of cells. In attempts to grow amphibian gonads for the study of problems of sex differentiation, it would seem that tissue extracts from amphibian sources might produce better growth of amphibian organs. Preliminary results are presented here in which gonads were placed in cultures containing tissue extracts of larval amphibians and compared with organs grown on media containing chick embryo extract.

This investigation was supported by grants from the American Philosophical Society, and the General Research Fund, Southern Illinois University.

MATERIALS AND METHODS

Second-year larvae of *Rana clamitans* were collected locally. Twenty-four hours before gonads were to be cultured the tadpoles were placed in a solution of 1% sulfadiazine in aerated tap water to which had been added 10 to 20 gamma/ml. of streptomycin sulfate (Wilde, 1948). Gonads were carefully removed, under aseptic conditions, from animals which had been anaesthetized with M. S. 222. Mesentery and fat bodies were dissected away and one gonad of each pair was placed in sterile Holtfreter's or Tyrode's solution for about two hours before it was put into culture. The other gonad of the pair was preserved as a control.

The composition of the two media used in this study was as follows:

MEDIUM I

Amphibian tissue extract (50%)	2 parts	16.7%
1% agar	6 parts	50.0%
Glass-distilled water	3 parts	25.0%
Streptomycin solution, 5 gamma/ml. in water	1 part	8.3%

MEDIUM II

Chick embryo extract (33%)	4 parts	20.0%
1% agar	13 parts	65.0%
Glass-distilled water	2 parts	10.0%
Penicillin, 1% solution in water	1 part	5.0%

Amphibian tissue extract was prepared from 20 *Rana clamitans* larvae from which the intestinal tract had been removed. The larvae were placed in a Waring Blendor and macerated for approximately five minutes. To the macerated tissue was added an equal volume of full strength Holtfreter's solution. When this mixture was homogeneous it was placed in 50 ml. tubes and centrifuged for 10 minutes at 3500 r.p.m. The supernatant fluid was then filtered through a Seitz bacterial filter (0.1 μ) and the filtrate placed in sterile vaccine bottles and refrigerated at 2 to 6° C.

The chick embryo extract was prepared from chick embryos which had been incubated for 11 days. Ten embryos were macerated in a Waring Blendor for 5 minutes, the resulting tissue was placed in 50 ml. centrifuge tubes and diluted to the following proportions: 2 parts embryonic tissue, 1 part Tyrode's solution with 1% glucose added, and 3 parts glass-distilled water. After centrifugation at 3500 r.p.m. the embryo extract was frozen at -4° C. before use.

In preparing final media an attempt was made to have the concentrations as nearly isotonic as possible for amphibian tissues. Watch glass cultures were made according to the method of Fell and Robison (1929) and gonads were placed on solid media. Cultures on Medium I consisted of 14 testes and 10 ovaries and on Medium II 8 testes and 22 ovaries. The maximum period of time for cultivation of these organs was 29 days.

Cultures were kept in a constant temperature cabinet at 24 to 26° C. and maintained at pH 7.2 to 7.4. Organs were transferred to fresh media each fifth day. At the end of the culturing period organs were fixed in Zenker's solution, sectioned at seven microns, and stained in Harris' hematoxylin and chromotrope 2-R.

Results

As criteria for determining which medium was most nearly ideal for growth and maintenance of amphibian testes and ovaries, the following conditions were observed: proliferation and migration of cells, maintenance of organs without growth, and degree of necrosis (Table 1).

Ovaries appeared to grow and retain their characteristic form better than did testes, although auxocytes in the ovaries showed progressive degeneration beginning during the first week of the culture period (Fig. 1, A, E). This condition is usually found in ovaries where insufficient amounts of gonad-stimulating or sex hormones are present. Other cells of the organ did not show much degeneration. Both types of gonads seemed to grow better on media containing chick embryo extract (Fig. 1), with most of the cellular growth occurring among the non-germinal cells. The term non-germinal is employed to designate follicle cells, granulosa, theca, stroma, and peritoneum. Occasionally, immature germ cells or even auxocytes were carried with the non-germinal cells as they migrated (Fig. 1, C); however, the greatest cell proliferation occurred among the granulosa cells (Fig. 1, B). This was particularly noticeable in ovaries where degeneration of auxocytes occurred since,

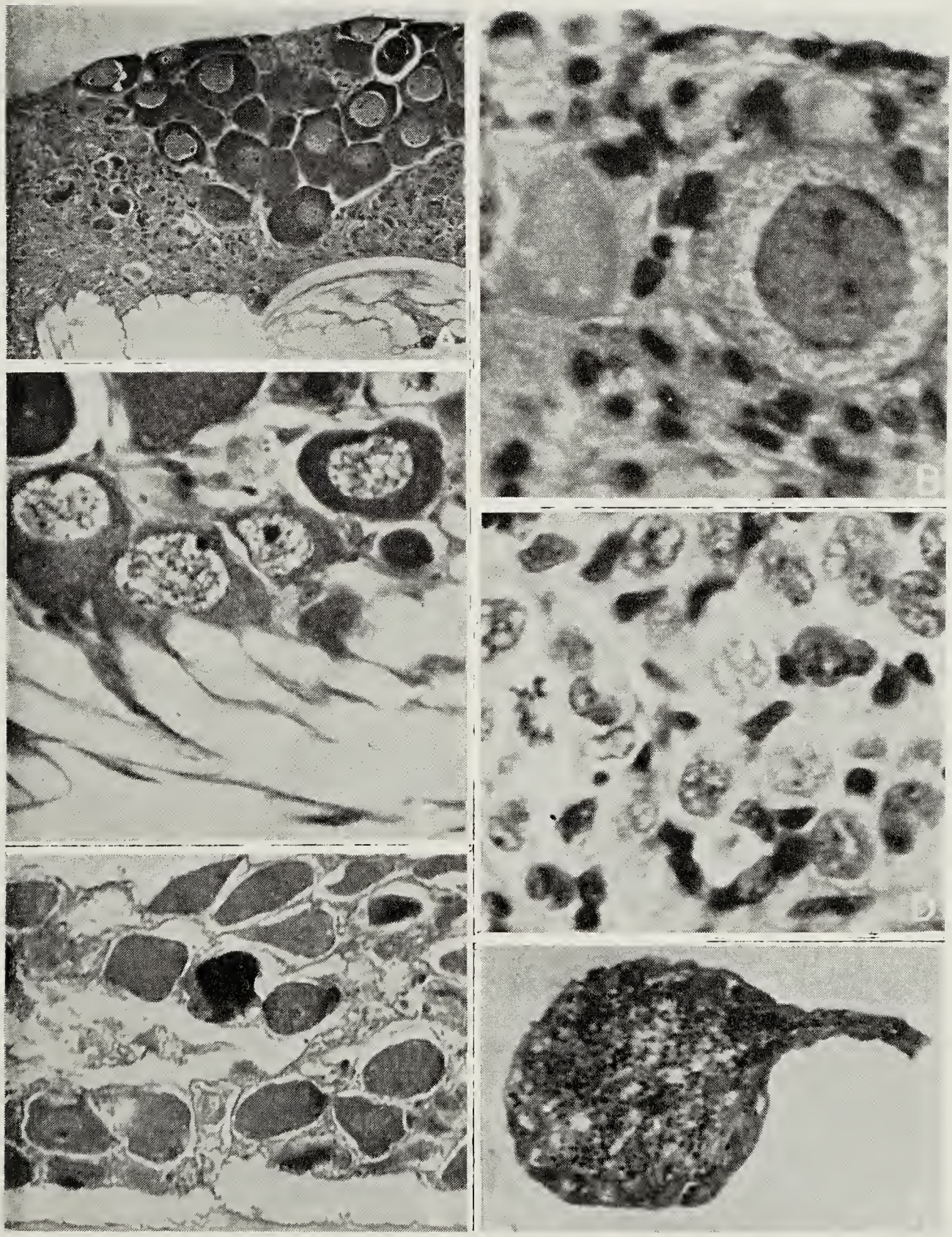

FIG. 1.—*A*, ovary, X60; *B*, ovary, X500; *C*, ovary, X250; *D*, testis, X500; *E*, ovary, X120; *F*, testis, X120. *A*, *B*, *C*, *D*, on Medium I; *E* and *F*, on Medium II. Culture time, 28 days.

as the large cells decreased in size, the granulosa cells filled in the space in the follicle. There were mitotic figures, not only in non-germinal cells, but in germ cells as well (Fig. 1, D).

No mitoses were observed in organs grown on amphibian tissue extract, and there were only isolated cases in which a few non-germinal cells had migrated from the explant. In some instances both ovaries and testes appeared to be well maintained with cells in their characteristic form, although in others partial or complete necrosis occurred (Fig. 1, E, F).

TABLE 1.—Numbers of Gonads Showing the Various Conditions Described.

	Amphibian tissue extract and agar (medium I)		Chick embryo extract and agar (medium II)	
	ovary	testis	ovary	testis
Growth and proliferation...	0	0	19	2
Maintenance without growth	7	5	0	3
Necrosis.....	3	9	3	3

DISCUSSION

From the results obtained in the present experiments it appears that amphibian gonads grow better on a medium containing chick embryo extract than on amphibian tissue extract. Had amphibian plasma or even chick plasma been added to the amphibian tissue extract better results might have been obtained. However, Preston (1949) and Boss (1954) reported that media containing cock plasma and chick embryo extract served adequately for growth of a variety of amphibian tissues.

For purposes of studying sex differentiation in the amphibian gonad it appears that the best medium would be chick embryo extract and agar. On this medium there is little cellular migration, with few changes in cell form. There is cell multiplication among non-germinal cells and germ cells. This medium appears to be adequate.

While some necrosis occurred on all types of media, ovaries were better maintained than testes. This may be due to the fact that the ovaries with a larger surface area exposed to the medium absorbed greater amounts of nutritive material than testes with a much smaller surface area. It may also be taken into account that some of the deutoplasm from degenerating auxocytes may have been utilized by other cells, but most of the nutriment for the organs came from the medium.

SUMMARY AND CONLUSIONS

1. Ovaries and testes of second-year *Rana clamitans* larvae grow well in organ cultures.
2. A medium containing chick embryo extract causes some cellular migration, but germ cells as well as non-germinal cells multiply in both ovaries and testes.
3. There is little growth of organs on a medium of amphibian tissue extract and agar, although 50% of the organs can be maintained on this medium without apparent cellular change.

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FOOD OF THE COTTONTAIL IN SOUTHERN ILLINOIS

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INTRODUCTION

The cottontail rabbit, *Sylvilagus floridanus* Allen, is the most popular small game mammal in North America (Trippensee, 1948). Because of its wide-spread occurrence and abundance, several million are harvested for sport and food (Hamilton, 1943). In Illinois, hunters take more cottontails than any other game animal, with the bulk of the hunting pressure and kill occurring in the southern counties (Marquardt and Scott, 1952). This distribution of harvest probably reflects the favorable habitat of the southern one-third of Illinois.

Previous investigations of the cottontail in Illinois have largely emphasized population levels and factors affecting these levels (Yeatter and Thompson, 1952; Mohr, 1947; Ecke, 1955). The present research was undertaken to learn something about the food habits of cottontails in southern Illinois. The objectives included: an evaluation of items utilized as food; seasonal variation in food utilization; and, relationship of food utilization to land use. The period of investigation extended from January 1, 1952, to December 31, 1952.

STUDY AREAS

Two areas located in Williamson County, Illinois, were chosen for study. These included the T. M. Hill Farm, consisting of 72 acres about 3 miles east of Carterville, and 580 acres of the Crab Orchard National Wildlife Refuge 5 miles west of Marion. These areas were selected because of variety in the land use, apparent available food and cover, and absence of hunter disturbance. No attempt was made to determine the cottontail population because it was not considered highly essential to the project. Nevertheless, the large number of observations of fecal pellets and cuttings on vegetation indicated that sizable populations inhabited the two areas.

In 1952 snowfall and rainfall were subnormal and temperatures above normal (U. S. Commerce Comm., 1953). Much of the palatable vegetation became dry and undesirable during the summer as high maximum temperatures probably increased the rate of transpiration and thus hastened the drying of the plants. As a result of abnormally high minimum temperatures, many grasses contained a high moisture content during the winter. Only a small amount of snow fell during the year and this melted after a few hours.

T. M. Hill Farm.—The T. M. Hill Farm consisted of 20 acres of corn, 20 acres of soybeans, 2 acres of apple orchard, 5 acres of woodland, 20

acres of pasture, 1 acre of garden, 2 acres of fallow ground, and 2 acres of building sites, as a result of the agricultural program of 1951. In 1952, 5 and 20 acres were planted to soybeans and corn, respectively. The remaining land was allowed to lie idle and produced a heavy growth of weedy herbaceous plants.

Protective cover was available in the idle fields and orchard in the form of dense growths of broomsedge interspersed with patches of dewberry, blackberry, and Kentucky bluegrass which cottontails readily utilize for forms (Horsley, 1942). Plant growths in the fence rows, consisting of grasses, weedy herbaceous plants, and woody shrubs, furnished cover between the croplands in 1951; this cover was removed in late summer, 1952.

Crab Orchard National Wildlife Refuge.—The Refuge area was about equally divided into agricultural and non-agricultural use in 1951 and 1952. Of 303 acres which comprised the agricultural land in 1951, 65 acres were in corn, 86 acres in soybeans, 30 acres in sweet clover, 66 acres in red clover, 43 acres in lespedeza, and 13 acres in unattended apple orchards. During the 1952 growing season, 40 acres were planted to soybeans, 150 acres to corn, 20 acres to wheat, and the remaining land was allowed to lie idle. The 277 acres of permanent non-agricultural land included: fallow land, 21 acres; old building sites, 3 acres; shop and building areas, 27 acres; railroad right-of-ways, 10 acres; shrub growths, 144 acres; and woodland, 72 acres. The fence-row growth was similar to that of the T. M. Hill Farm and was allowed to grow to furnish food and cover for wildlife.

Materials and Methods

Investigations of foods utilized by the cottontails were made from fecal pellets collected from the two study areas at 10-day intervals during a 12-month period. Only freshly dropped pellets were collected, being distinguished by a shiny mucous coating. One to two pellet samples were collected from each deposit found and stored in coin envelopes. Analyses of the samples were made according to the methods described by Dusi (1949). Fecal pellets were used because they were easier to collect and store than stomachs; also it was possible to obtain a continuous collection of pellets from the same population to evaluate better the seasonal aspects of food. According to Baumgartner and Martin (1939) histological studies are more desirable than the usual laboratory methods.

As the pellets were relatively homogenous, only one-eighth of each was mounted on a microscope slide. Permanent slides were produced using Apathy's Gum Syrup as a mounting medium (Richards, 1943). Each slide was systematically examined with a compound microscope. Food items were identified by carefully surveying the fecal material and comparing the cells with prepared reference slides. The percent volume of each food item was estimated from the average of five low-power readings, one from each of the four corners of the slide and one from the center.

Prior to preparation of the pellet slides a reference collection of plants

was made and slides prepared. Tissues of leaves, fruits, buds, and bark were obtained and preserved in vials containing formalin - aceto - alcohol (Johansen, 1940). A maceration technique was used to separate the cells of the plants for staining (Dusi, 1949). Small pieces of plant material were placed in a solution of equal parts of 10% nitric acid and 10% chromic acid until the tissues could be teased apart; plant cells were stained in Mayer's hemalum. When it was possible to strip the epidermis from fresh leaves, the tissue was put through a series of alcohol dilutions before staining (Dusi, 1949).

To supplement analyses of the pellets, cuttings of vegetation by cottontails were noted as the areas were traversed in search of pellets. No observations of feeding cottontails were recorded, as the collections were made near the middle of the day when the cottontail was less active. Sweetman (1949) reported that, although cottontails were observed to prune or "bark" plants, this was not significant as an indication of food acceptability. Nevertheless, in this study it was assumed that, if considerable cutting had been done, the cottontails probably used some of these materials as food. Observations of cuttings of vegetation were an important aid in the determination of foods by histological methods, as field data often provided leads to the identity of plants being utilized.

Analysis of Results

Of the 290 samples collected for analyses, 117 were obtained from the T. M. Hill Farm from January 19 to December 6, 1952, and 173 from the Crab Orchard National Wildlife Refuge from January 5 to December 26, 1952. A total of 15 food items was identified in the samples collected from the Hill Farm and 12 food items from the Refuge. Although a large portion of the contents of each pellet could not be identified, it was believed that the general feeding trends of cottontails were indicated. Possibly much of the unidentifiable material was conductile tissue from plants whose identity was established.

T. M. Hill Farm.—On a monthly basis and according to volume, corn ranked first as a food item during January, February, April, May, September, and December and ranked number two in March and November at which time wheat and apple fruit ranked first, respectively (Fig. 1). Corn was not recorded during four months when broomsedge in June, soybeans in July and August, and Kentucky bluegrass in October ranked first by volume. Foods of lesser importance on a monthly basis were dewberry, blackberry, lespedeza, Canada bluegrass, sassafras, and red top. Other items, though occurring with some frequency, were not important from the standpoint of volume.

Analyses of the seasonal pattern of identifiable foods used by cottontails indicated: corn (7%), Kentucky bluegrass (4%) and apple fruit (3%) as the top-ranking foods in winter; broomsedge (17%), corn (8%), Kentucky bluegrass (3%), wheat (3%) and lespedeza (3%) in spring; soybeans (35%), apple fruit (7%), corn (3%) and sassafras (2%) in summer; and, apple fruit

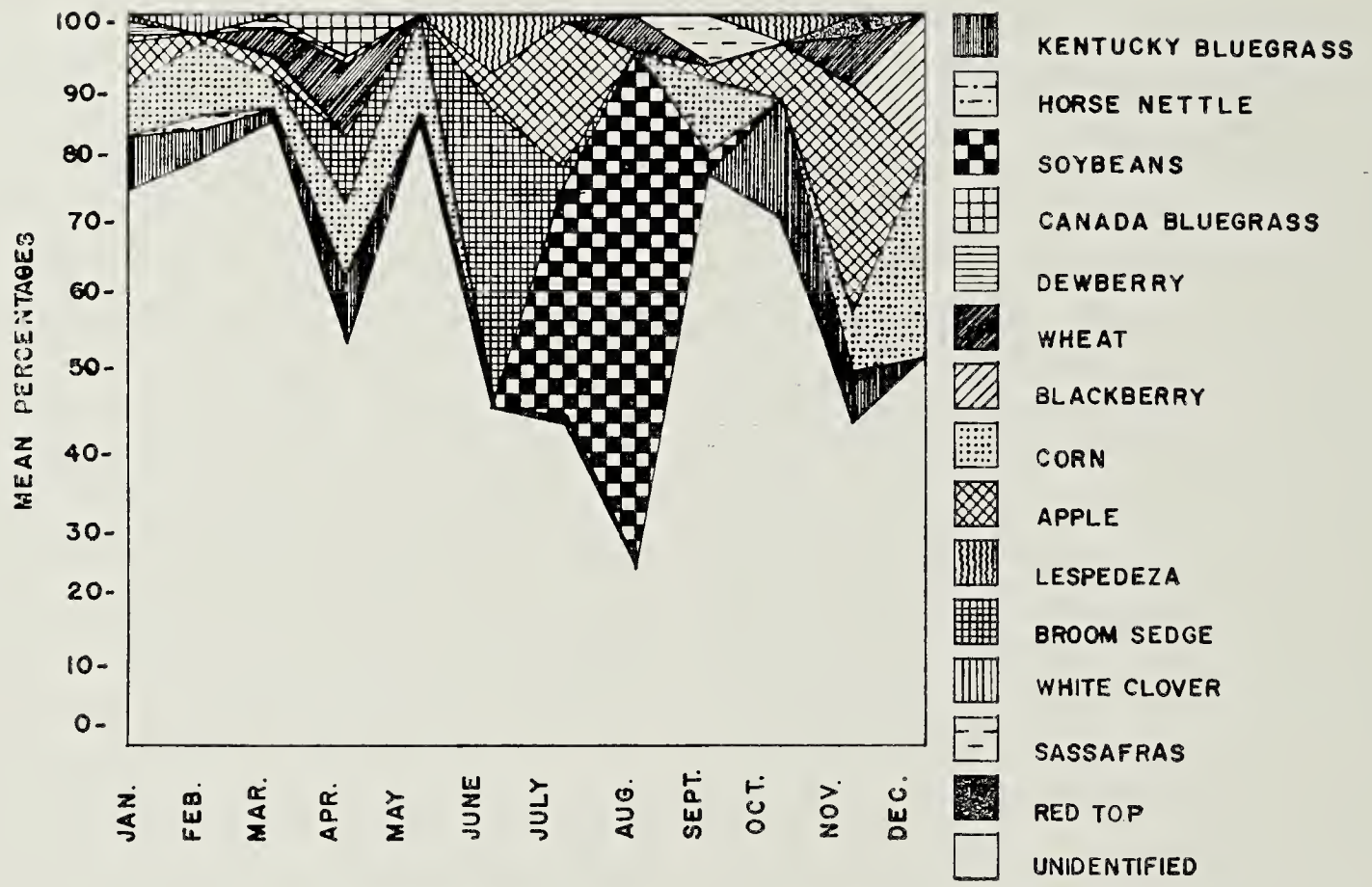

FIG. 1.—Monthly food habits of cottontails, T. M. Hill Farm.

(13%), corn (12%), Kentucky bluegrass (8%), blackberry (7%) and wheat (2%) in fall (Fig. 2). Corn, Kentucky bluegrass, apple fruit, wheat, and lespedeza appeared in the cottontail diet during each of the four seasons. However, the greatest utilization of a food item during any one season was that of soybeans in summer.

On the basis of per cent volume the annual diet showed the 10 top-ranking foods to be soybeans, corn, apple fruit, broomsedge, Kentucky bluegrass, wheat, blackberry, lespedeza, Canada bluegrass, and sassafras (Table 1). According to frequency of occurrence, apple fruit, Kentucky bluegrass, corn, soybeans, and lespedeza appeared in 10% or more of the samples.

Crab Orchard National Wildlife Refuge.—On the Crab Orchard Refuge trends in food habits of cottontails by month-periods showed Kentucky bluegrass as the top-rated food item during six months—February, March, April, July, October, and November (Fig. 3). Canada bluegrass was number one in January, soybeans in June and August, horse nettle in May, dewberry in September, and wheat in December. Except for February, June and December, corn and wheat were of no great importance in the diet of cottontails. The utilization of soybeans increased from 16% of the total volume in June to 57% in August, after which time it was not recorded. Horse nettle was identified in samples from all months except July and November, yielding from less than 1% to 49% (May) of the total volume for any one month. Primarily fruit and seeds of the plant were found in the pellet material, but cells of the leaves and stems were occasionally noted. Foods of lesser importance by month included apple fruit, lespedeza, dewberry, and blackberry.

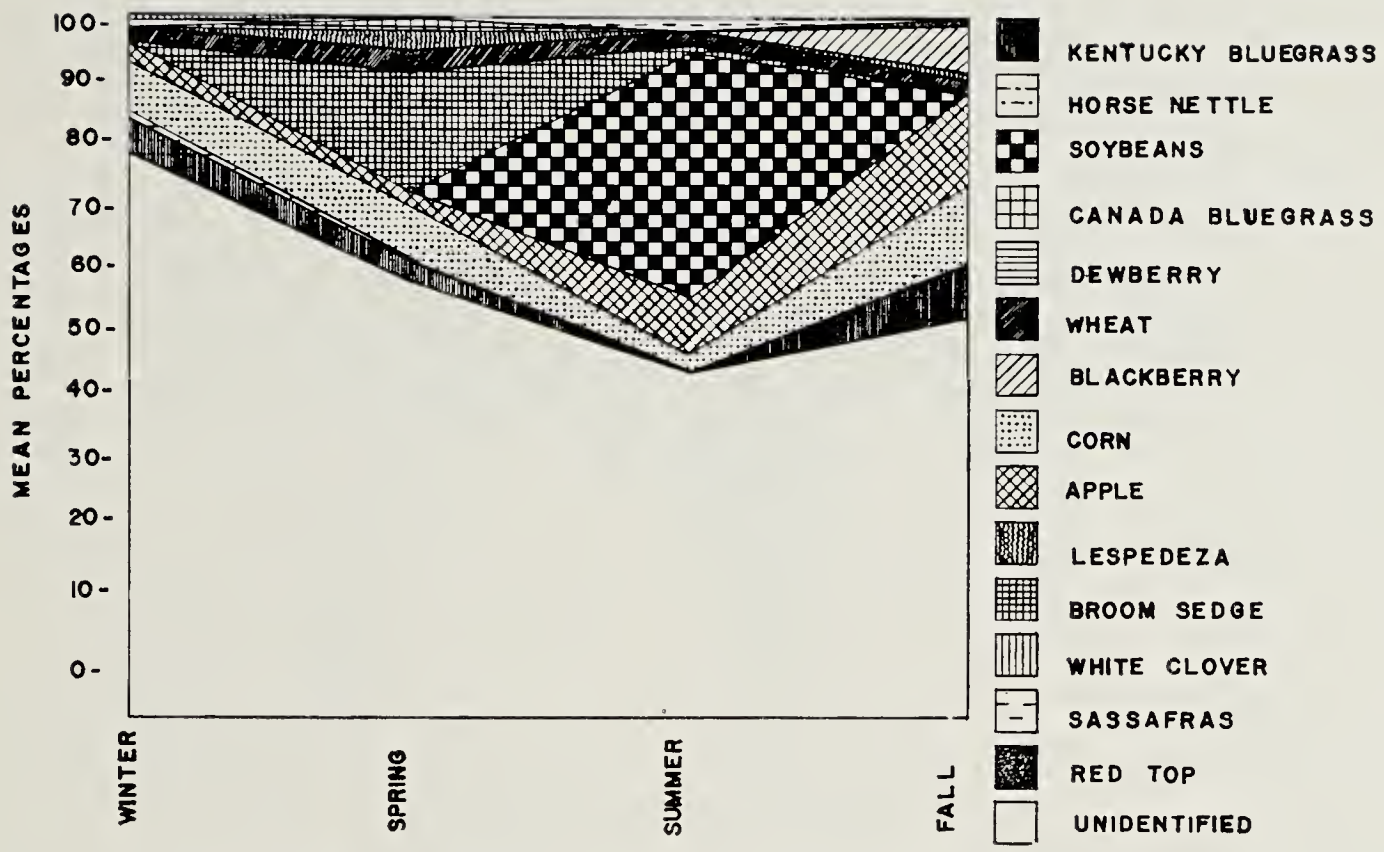

FIG. 2.—Seasonal food habits of cottontails, T. M. Hill Farm.

TABLE 1.—Summary of Trends in Foods of Cottontails on the T. M. Hill Farm, January 19—December 6, 1952.

Food items	Percent frequency of occurrence	Percent volume
Soybean	13.0	9.0
Corn	15.0	7.0
Apple	25.0	6.0
Broomsedge	9.0	5.0
Kentucky bluegrass	22.0	4.0
Wheat	6.0	2.0
Blackberry	4.0	2.0
Lespedeza	10.0	1.0
Sassafras	1.0	1.0
Canada bluegrass	2.0	1.0
Dewberry	3.0	trace
White Clover	1.0	trace
Red top	1.0	trace
Horse nettle	2.0	trace
Goldenrod	1.0	trace
Unidentified	92.0	61.0

Kentucky bluegrass and horse nettle ranked high in importance as all-season foods, being the only two items taken in appreciable quantities from spring through winter (Fig. 4). Soybeans (32%) were the number one food in summer, Kentucky bluegrass in winter (23%) and fall (18%), and horse nettle (18%) in spring. Canada bluegrass

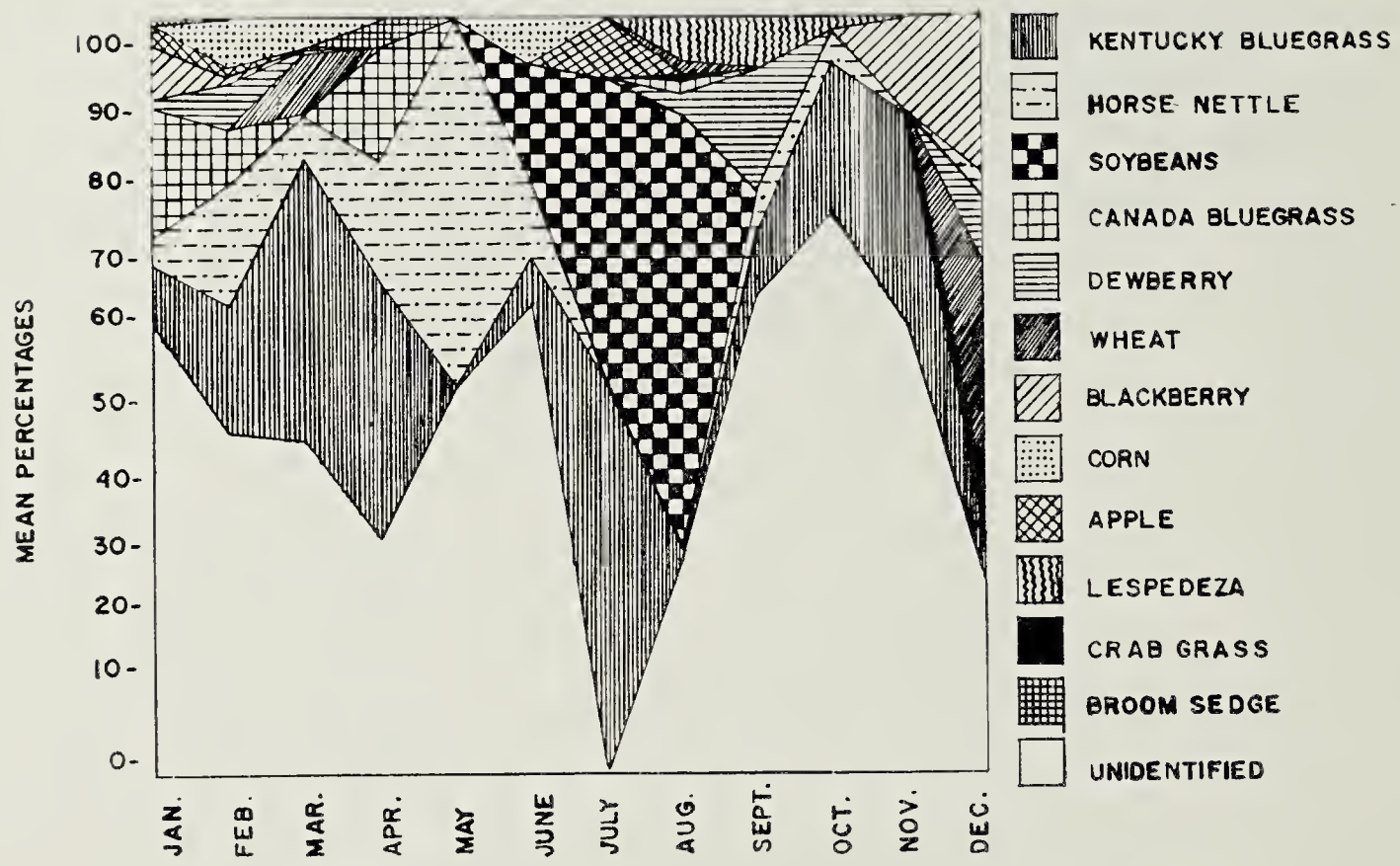

FIG. 3.—Monthly food habits of cottontails, Crab Orchard National Wildlife Refuge.

TABLE 2.—Summary of Trends in Foods of Cottontails on the Crab Orchard National Wildlife Refuge, January 5—December 26, 1952.

Food items	Percent frequency of occurrence	Percent volume
Kentucky bluegrass	51.0	19.0
Soybean	8.0	10.0
Horse nettle	25.0	8.0
Wheat	6.0	4.0
Canada bluegrass	13.0	3.0
Blackberry	6.0	3.0
Dewberry	13.0	3.0
Corn	6.0	1.0
Lespedeza	5.0	1.0
Apple	2.0	1.0
Broomsedge	2.0	trace
Crab grass	1.0	trace
Partridge pea	1.0	trace
Unidentified	70.0	46.0

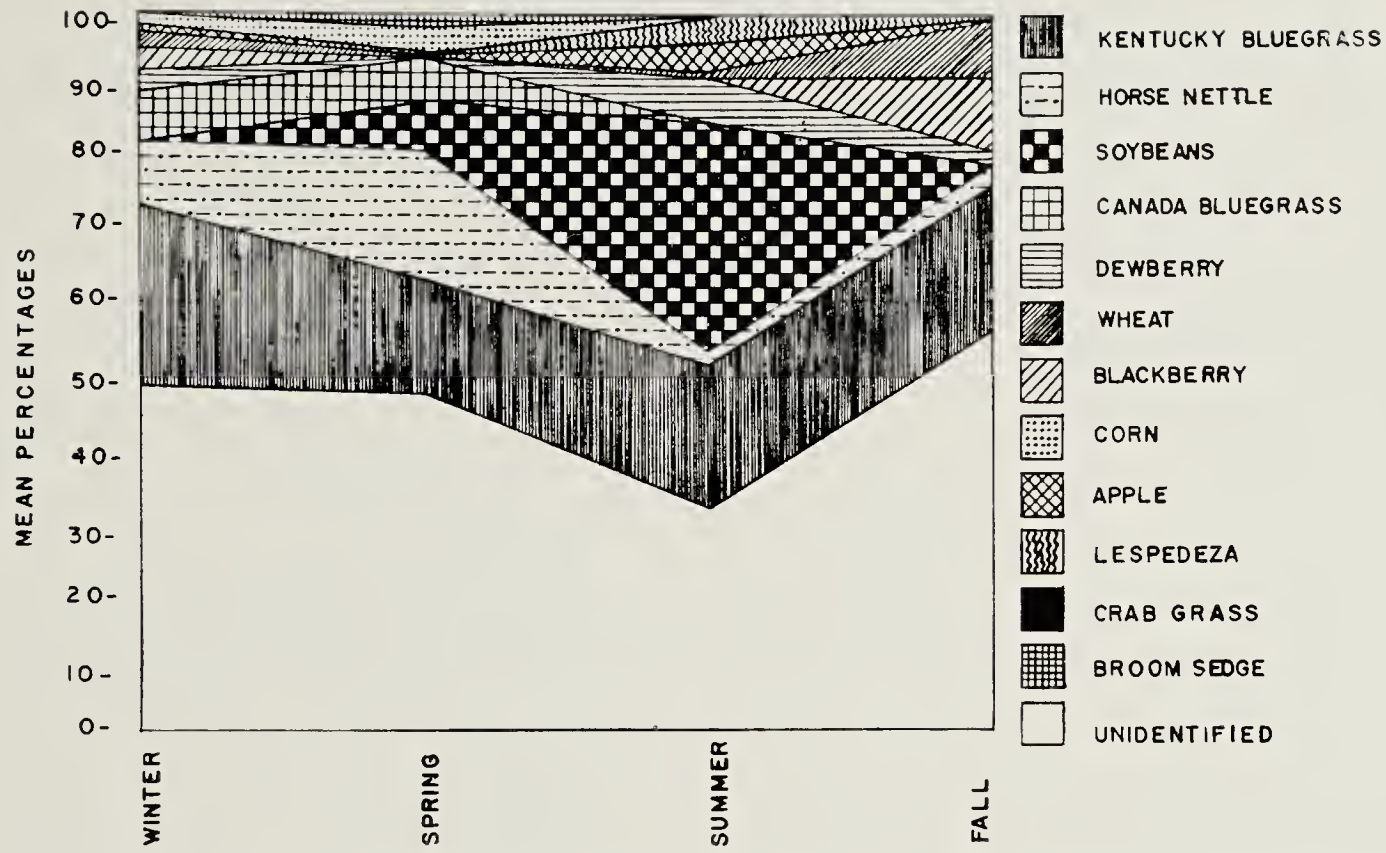

FIG. 4.—Seasonal food habits of cottontails, Crab Orchard National Wildlife Refuge.

was important as a winter (7%) and spring (6%) food. Other foods of seasonal importance were corn in winter (3%) and spring (3%), apple (3%) and lespedeza (4%) in summer, dewberry in summer (6%) and fall (2%), and blackberry in fall (10%) and winter (3%), and wheat (11%) in winter.

On an annual basis the number one identifiable food of the cottontail on the Crab Orchard National Wildlife Refuge in 1952 was Kentucky bluegrass (Table 3). According to frequency of occurrence, horse nettle, dewberry, and Canada bluegrass were second, third and fourth in importance, while by volume, soybeans, horse nettle, and wheat were second, third and fourth, respectively.

Observation of cuttings revealed 14 plants, as possible cottontail foods, which were not identified in the histological procedures (Table 3). There was no way of determining the per cent volume and frequency of occurrence of these foods, but it was apparent that some were utilized more than others. Those foods, identified only by cuttings, which seemed to be favored by the cottontail were poison ivy, goldenrod, and ragweed. Only an occasional cutting was noted on the other plants.

DISCUSSION

These data indicated that the cottontail in southern Illinois relied on herbaceous plants almost entirely for a source of food in 1952. It has been suggested by Sweetman (1949) and Dusi (1952) that snowfall was an important factor in influencing the change from herbaceous to woody plants. Because herbaceous foods were plentiful on the two study areas and snowfall was light, cottontails probably were not forced to make extensive utilization of woody plants. It was evident, however, that dewberry and blackberry were utilized the greatest during the fall and win-

TABLE 3.—Plants Considered Available to Cottontails for Food, T. M. Hill Farm and Crab Orchard Wildlife Refuge.

Common name	Scientific name (Fernald, 1950)
Cedar	*Juniperus virginiana* L.
Canada bluegrass (1, 2)*	*Poa compressa* L.
Kentucky bluegrass (1, 2)	*Poa pratensis* L.
Tumble grass	*Erogrostis spectabilis* (Pursh.) Steud
Purple top	*Tridens flava* (L.) Smyth.
Wheat (2)	*Triticum aestivum* L.
Red Top	*Agrostis alba* L.
Common timothy (1)	*Phleum pratense* L.
Crab grass (2)	*Digitaria sanguinalis* (L.) Scop.
Paspalum (1)	*Paspalum circulare* (Nash.) Fern.
Bristly foxtail (2)	*Setaria* sp. Beauv.
Broom-sedge (1, 2)	*Andropogon virginicus* L.
Corn (1, 2)	*Zea mays* L.
Garlic (1, 2)	*Allium* sp. L.
Lily (2)	*Lilium* sp. L.
Hickory	*Carya* sp. Nutt.
Hazelnut (1)	*Corylus americana* Walt.
Oak	*Quercus* sp. L.
Elm (1)	*Ulmus* sp. L.
Dock (1, 2)	*Rumex* sp. L.
Smartweed	*Polygonum* sp. L.
Pokeweed	*Phytolacca americana* L.
Sassafras (1, 2)	*Sassafras albidum*
Apple (1, 2)	*Pyrus malus* L.
Crab apple (1)	*Pyrus augustifolia* Ait.
Blackberry (1, 2)	*Rubus* sp. L.
Dewberry (1, 2)	*Rubus* sp. L.
Rose (2)	*Rosa* sp. L.
Honey locust (2)	*Gleditsia triacanthos* L.
Partridge pea (2)	*Cassia fasciculata* Michx.
Red clover	*Trifolium pratense* L.
White clover	*Trifolium repens* L.
Yellow sweet clover	*Melilotus officinalis* L.
White sweet clover	*Melilotus alba* Desr.
Lespedeza	*Lespedeza* sp. Michx.
Soybean (1, 2)	*Glycine max* (L.) Merr.
Wood sorrel	*Oxalis* sp. L.
Smooth sumac	*Rhus glabra* L.
Dwarf sumac	*Rhus copallina* L.
Poison ivy (1, 2)	*Rhus radicans* L.
Maple (2)	*Acer* sp. L.
Box elder	*Acer negundo* L.
Grape	*Vitis* sp. L.
Mare's-tail	*Hippuris vulgaris* L.
Wild carrot	*Daucus carota* L.
Horse-nettle (2)	*Solanum carolinse* L.
Trumpet creeper (2)	*Campsis radicans* (L.) Seem.
Common plantain	*Plantago major* L.
Japanese honeysuckle	*Lonicera japonica* L.
White snakeroot	*Eupatorium altissimum* L.
Goldenrod (1, 2)	*Solidago* sp. L.
Boltonia	*Boltonia asteroides* (L.) L. 'Her.
Fleabane (2)	*Erigeron* sp. L.
Ragweed (1, 2)	*Ambrosia bidentata* Michx.
Giant ragweed	*Ambrosia trifida* L.
Common ragweed	*Ambrosia artemisiifolia* L.
Coneflower	*Rudbeckia hirta* L.
Spanish needle (1, 2)	*Bidens* sp. L.
Prickly lettuce	*Lactuca scariola* L.

*(1) Plants of the T. M. Hill Farm on which cottontail cuttings were recorded.
(2) Plants of Crab Orchard Refuge on which cottontail cuttings were recorded.

ter seasons, suggesting that herbs and grasses were either less available or desirable during those periods.

Perennial grasses were utilized extensively during all seasons with Kentucky bluegrass being the most important. Similar findings were reported for the cottontail in Ohio (Dusi, 1952), but an Iowa study (Hendrickson, 1938) showed little utilization of grasses. Of the coarse grasses, this study indicated that broomsedge was acceptable during early stages of growth (June to August) when moisture content was high.

Agricultural crops constituted a major portion of the cottontail diet during the entire year as corn, soybeans, and wheat ranked among the top foods utilized. Apple fruit likewise yielded a substantial portion of the accepted foods. Studies in Iowa (Hendrickson, 1938) and Michigan (Trippensee, 1938) indicated little utilization of fruit but extensive use of the bark from apple trees. Presumably this represented cuttings on small trees rather than mature ones such as those on the study areas in this investigation. Of special interest was the rather extensive use of horse nettle, a plant occurring as a weed species in intertilled crops or recently fallowed land.

The trend of food habits by months and seasons showed a correlation between utilization and availability. Suggested also was the fact that certain foods were more acceptable during some seasons than others and that possibly less desirable ones were acceptable when preferred foods were less available. The use of Kentucky bluegrass and horse nettle indicated something of universal acceptance, whereas dewberry and blackberry may have represented a second or third choice. Corn and apple fruits were highly preferred as they occurred during all times that they conceivably were available. Soybeans were probably the most desired of any food available until such time as the plants reached maturity. Wheat utilization, limited to the leaves of young plants, was directly associated with volunteer growths following the late June harvest and with fall seedings.

In comparing the data from two study areas there was an obvious difference in the food habits of cottontails. Results from the T. M. Hill Farm showed a closer relationship of the cottontail diet with agricultural activities than those from the Crab Orchard Refuge. This could possibly be explained by the fact that because of the smaller areas of idle land on the Hill Farm and the greater interspersion of these areas throughout the cropland, cottontails had more extensive access to agricultural crops. Also, the small idle areas of the Farm possibly provided a lesser supply of acceptable foods than did the larger ones of the Refuge. To be considered too were the more desirable and diversified aspects of the habitat of the fallow and idle land of the Refuge which might have offered a more complete environment for cottontails than similar but smaller areas on the private farm. Thus, the cottontails on the Refuge were possibly less dependent upon agricultural lands for an adequate or supplementary source of food throughout the year. Evident, however, was the fact that the soybeans were a pre-

ferred food under any circumstance as they ranked number one on the Hill Farm and number two on the Refuge. It was apparent, then, that cottontails of southern Illinois had definite food preferences, that these preferences were closely associated with availability, and that within poorly defined limits fallow and idle land were possibly as acceptable as agricultural lands in the provision of suitable foods.

Acknowledgments

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A CLUE TO SPRING MOLT IN RACCOONS AS REVEALED IN ANALYSIS OF SCATS

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In a study of the food habits of the raccoon in Kansas, 705 scats were collected over a two-year period. The occurrence and abundance of hair of the raccoon found in each scat were recorded. Hair probably was taken internally when the animals groomed themselves. Most of these scats were collected in the fall of 1952 and 1953 with lesser numbers after these seasons (Stains, 1956:42). The sample size from December through July was small, ranging from 1 to 22 scats per month (average, 8), but the two years of data revealed similar trends.

Raccoon hair in the scats was recorded as absent, trace, few, common, abundant, or very abundant. Each of these categories was given a numerical value from 0 for absent to 5 for very abundant. Each scat then was given a numerical value according to the abundance of rac-

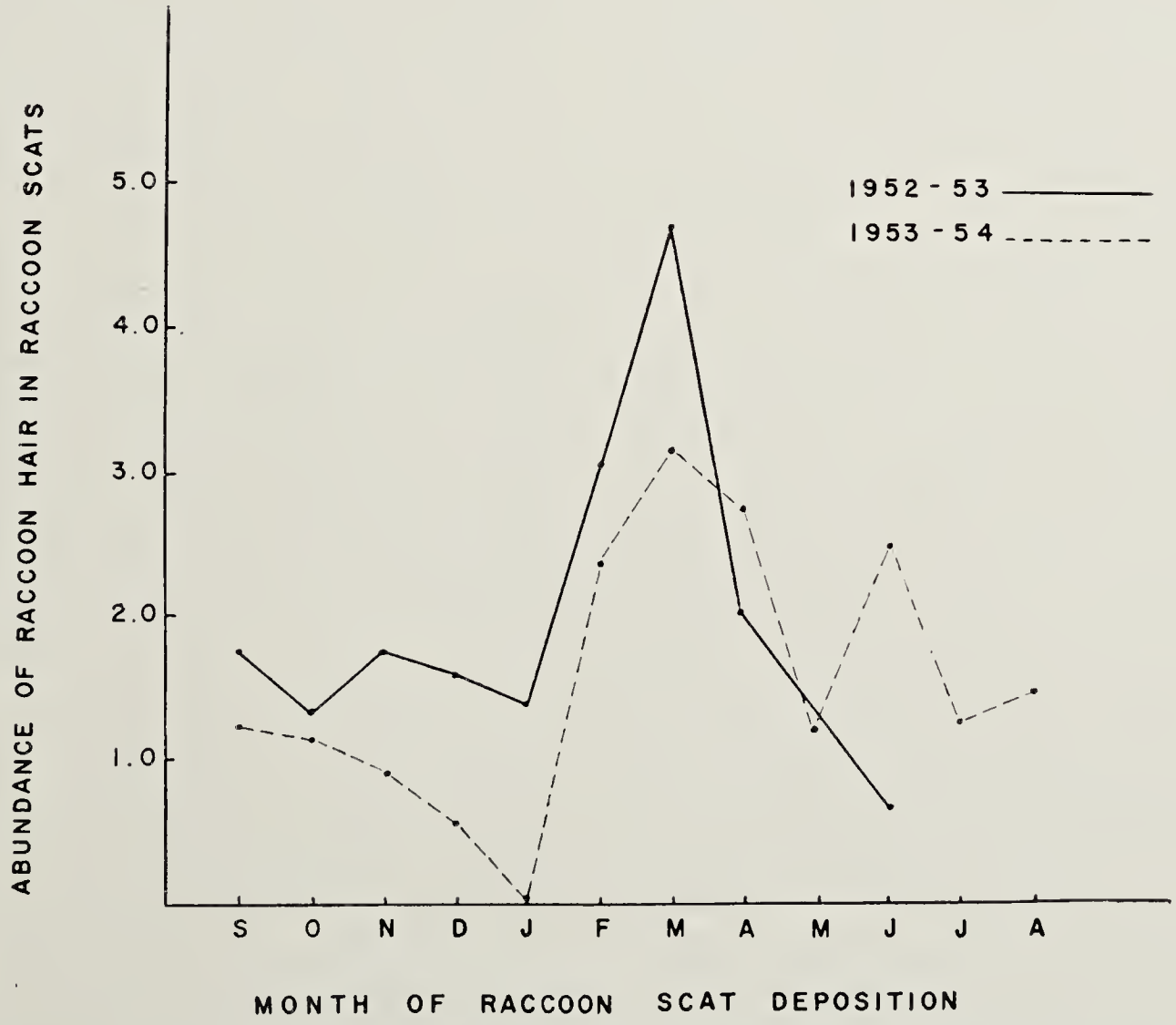

FIG. 1.—The abundance of hair in raccoon scats collected in different months.

coon hair found. An average monthly numerical value was computed and plotted (Fig. 1). The curves obtained show the peak of occurrence of hair in scats being reached in March in both years. This peak probably reflects the spring molt of hair from the body of the raccoon and illustrates that the molt occurring in the spring is a more rapid one than any occurring at other times of the year. The peak of the birth of litters occurs in late April and early May so that excessive grooming preparatory to litter birth may increase amount of hair in scats from females. The smaller peak shown in June may be the result of grooming the young, but a sample of two scats for this month in 1953 is too small for such conclusions. These curves also show that loss of hair is occurring throughout the year. The least loss of hair probably indicates that the raccoon pelt is in prime condition in late December through January. Seemingly the molt to winter pelage is a slow continuous process with the absence of any distinct peak.

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NESTING BIRDS OF THE SHORELINE AND ISLANDS OF CRAB ORCHARD LAKE, ILLINOIS

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A nesting bird survey was made at Crab Orchard Lake, Williamson County, Illinois, in 1951 and 1952 to determine: 1) the species which utilized the shoreline and islands for nesting purposes; 2) the numbers of individual species; and 3) the degree of nesting success.

Previous investigations at Crab Orchard were limited to a detailed study of the great blue heron, *Ardea herodias* (Lopinot, 1950), to a study of the aquatic vegetation (Hankla, 1952), and to observations by representatives of the Crab Orchard National Wildlife Refuge and of the Wildlife Research Laboratory, Southern Illinois University.

This study is of value as a record of nesting birds which utilize the existing marsh and island habitats. It will serve as a reference for later studies and provide a source for comparison with conditions which should develop during future years as the result of expected successional changes.

Materials and Methods

A preliminary survey of the shores and islands of Crab Orchard Lake was made in March, 1951, and investigations were continued in specific areas until July, 1951. The study was resumed in March, 1952, and continued until August. Other pertinent observations were made during the intervening months.

Nests on the islands were located by traversing the breadths of the islands in parallel strips, the widths of which depended on the density of cover. Nests were located in the marsh areas by walking through the center of the lengths of cat-tail stands which were six feet or less in width. Wider cat-tail stands were surveyed by moving through at intervals of two to five paces depending on the density. The recording of nest data included: 1) size; 2) height, if above ground; 3) apparent depth in vegetation; 4) distance between nests; 5) distance from water's edge; 6) presence or absence of eggs; and 7) presence or absence of adult birds. Outline maps showing outstanding habitat features were made of bays selected for detailed observations. Positions of nests were noted on these by numbering; data on eggs and young were recorded three to five times weekly.

Relevant data for the years prior to this study and for supplementing this study were obtained from Crab Orchard National Wildlife Refuge Narrative Reports (Anon., 1949-1952). Valuable data were also obtained by interviews with personnel at the Crab Orchard National Wildlife Refuge.

Description of Area

Crab Orchard Lake, completed in 1940 and filled to crest elevation in 1942, has a surface area of approximately 6,500 acres and a shoreline of 126 miles. Twenty islands, varying in size from one one-hundredth acre to ten acres, are present in the lake (Hankla, 1952).

The distribution of shoreline vegetation is determined by the youthfulness of the lake and by various environmental conditions. Because it is a young lake, changing conditions of the shoreline are to be expected as the result of the operation of successional forces. However, adverse environmental conditions tend to produce effects which retard or prevent vegetative growth in many sections of the lake. Prevailing winds cause waves which sweep across the lake with great force. Particularly affected are the vertical, exposed banks of the mainland and islands, which receive full impact of the erosive action of waves. Vegetation has no opportunity to become established on such banks because of severe erosion, instability of infertile silt materials, and the lack of available organic debris. These barren areas thus account for many miles of shoreline which are not used by nesting birds.

Narrow bands of cat-tail, *Typha latifolia,* are prevalent in the western section of the lake, where a more gently sloping shoreline grants at least partial protection from wave action. The cat-tail stands become quite extensive in the north-western bay areas, where more typical marsh conditions prevail. Buttonbush, *Cephalanthus occidentalis,* is present in many marsh areas, particularly in the eastern section, and is in varying degrees of abundance.

The vegetative cover of the islands consists primarily of such invaders as broomsedge, *Andropogon virginicus,* and blackberry, *Rubus* sp. Occasional trees of former timber and orchard areas are present on the islands, as are small stands of black willow, *Salix nigra,* and persimmon, *Diospyros virginiana.*

In 1947, Crab Orchard Lake was included in the newly established Crab Orchard National Wildlife Refuge, under the jurisdiction of the U. S. Fish and Wildlife Service (Hankla, 1952). With the development of protected open waters, local feeding areas, and improved shore habitats, numerous migratory and resident species of birds remained at the lake for extended periods of time.

Nesting Birds

The present investigation revealed that 12 species of birds, representing 6 families, utilized the marshes and islands of Crab Orchard Lake for nesting purposes (Table 1).

Nine of these species may be considered rare marsh and island nesting birds, as only from one to eight nests and (or) broods of each species were observed in the study area. These species include the pied-billed grebe, green heron, American bittern, least bittern, mallard, black duck, osprey, king rail, and American coot.

The survey revealed that the great blue heron rookery, established in 1945, was undergoing a decrease in the breeding population. The number of active nests declined from

134 in 1948 (Lopinot, 1950) to 36 in 1952.

Canada geese were found to be utilizing the broomsedge cover of the islands for nesting purposes. Of the 49 escaped decoy birds present in 1950, four pairs were found to have nested (Anon., 1950). Three nests were located in 1951 and nine in 1952. Of this total of 16 nests, 10 were known to be successful, with time of hatching occurring from April 22 until May 14. There were three to six eggs in completed clutches. Additional nests were believed to have been constructed during this period as evidenced by observations of 17 immature Canada geese in 1950, 27 in 1951, and 35 in 1952. Losses of young in a two-months period after hatching were estimated to be from 20% to 60% of the total hatch. Although positive evidences of the causes of mortality were not obtained, possible threats to the young were believed to include not only sudden severe wind and rain storms, but also predators, such as: snapping turtles, *Chelydra serpentina;* birds of prey, Falconiformes; foxes, *Urocyon cineroargenteus* and *Vulpes fulva;* raccoon, *Procyon lotor;* and fishermen.

A large breeding population of eastern red-wings was present at Crab Orchard Lake from March until September, making use of the marshes during the periods of breeding, nesting, and raising of young. In the western part of the lake, numerous red-wing nests were built in cat-tail stands, while occasional nests were in black willow and buttonbush. Nests of small groups and scattered pairs were constructed in cat-tails, shrubs, and trees in the eastern part of the lake. On the islands, it was found that trees (black willow; persimmon; elm, *Ulmus* sp.; and box elder, *Acer negundo*) contained nests.

In 1952, a total of 547 red-wing nests was constructed in cat-tails along 8 miles of shoreline, with the greatest density of nests being noted in the stands of protected areas. The average number of nests was found to be 35 in typical protected areas approximately 100 yards in length, whereas, in unprotected cat-tail areas of equivalent length, the average number was 7 nests.

The nesting period of red-wings was from early May until late July. Typical clutches contained four eggs, although clutches were observed with two, three, and five eggs. A 12-day period was the usual time of incubation. Observations of 547 nests indicated a high rate of fertility in 1952, as only four eggs, in separate nests, failed to hatch. Predation by birds appeared to be low. Of 230 active and inactive nests observed in July, 1952, 5% showed evidence of disturbance by unknown agents. This fact seemed to indicate a low predation rate, even though the nests were built in areas highly subject to human interference arising from fishing activities.

Observations indicated a high percentage of nesting success, with an average of three young per nest reaching fledgling stage. Basing estimates on this figure, at least 1600 young red-wings were produced in nests observed in this study, and a minimum of 10,000 young were produced on the entire lake.

TABLE 1.—Birds Utilizing Shoreline and Islands of Crab Orchard Lake, Illinois, as Indicated by Field Survey, 1949-1952.

Species	Nests				Young			
	1949	1950	1951	1952	1949	1950	1951	1952
Pied-billed grebe, *Podilymbus podiceps*	.....	.....	.....	.....	.....	4	2	1
Great blue heron, *Ardea herodias*	110	75	59	36	225[2]	225[2]	.....	.....
Green heron, *Butorides virescens*	.....	.....	.....	7	200-300[2]	200-300[2]	200-300[2]	200-300[2]
American bittern, *Botaurus lentiginosus*	.....	.....	.....	4	.....	2	4	2
Least bittern, *Ixobrychus exilis*	.....	.....	.....	8	.....	4	2	4
Canada goose, *Branta canadensis*	1	4	3	9	4	17	27	35
Mallard, *Anas platyrhynchos*	.....	.....	2	.....	14	20	10	14
Black duck, *Anas rubripes*	.....	.....	.....	1	.....	4	.....	.....
Osprey, *Pandion haliaetus*	1	1	1	1	1	1	1	1
King rail, *Rallus elegans*	.....	3	.....	.....	.....	.....	.....	27
American coot, *Fulica americana*	.....	1	.....	.....	5	18	5	11
Eastern red-wing, *Agelaius phoeniceus*	.....	.....	.....	547[1]	.....	.....	.....	1600[2]

[1] Number of nests found along eight miles of cat-tail shoreline.
[2] Estimate.

Discussion

The results of the survey indicate that only individuals of a few wintering and migratory species, other than the eastern red-wing, utilize the shoreline and islands of Crab Orchard Lake during the nesting season. This may be accounted for, in part, by the fact that Southern Illinois is outside the breeding ranges of many of these species, and, in some instances, is in the fringe area of the ranges. Therefore, the few individuals which do nest at the lake are possibly all which could be expected. Also, marsh-dwelling types, which migrate into southern Illinois during the nesting season, generally disperse and seek secluded, widely separated nesting sites. Never present in extremely large numbers, as are species with flocking tendencies, their dispersing activity would result in few individuals utilizing Crab Orchard Lake.

Continued use of nesting cover at the lake, by increased numbers of birds, will depend to a large extent on the return of birds raised there. If the homing instinct is strong in forms which are now known to nest, an increase in future nesting activity might be expected. Perhaps certain species of waterfowl, which are influenced by the homing instinct and return to established breeding grounds, would be able to nest successfully at Crab Orchard Lake. It might be possible to establish the lake as the breeding ground for various species, such as the mallard, black duck, and blue-winged teal. To do so would probably involve pinioning 500 to 1,000 birds and releasing them prior to the nesting season. Theoretically, the young of these birds would return, and in time, a larger breeding population might be established.

Increasing suitable habitat might also serve to attract additional nesting birds to the area. The construction of off-shore breakers in areas of eroded shoreline would be of value in alleviating the destructive wave action and would give vegetation an opportunity to become established. Planting of marsh-type vegetation has already proven successful in selected bay areas. Increased use of this procedure in bay areas, or combined with use of breakers in the main body of the lake, would hasten stabilization of the shoreline.

Human interference may be considered a prime factor which determines nesting success and continued nesting bird occupancy of the lake's marsh areas. The presence and activities of humans are believed to interfere seriously with many nesting birds. Finding of nests by fishermen and others who frequent stabilized areas of marsh vegetation often results in either destruction of nests and eggs or removal of eggs. At the present time, no portion of the refuge is inviolate during the nesting season. The human factor could be controlled by developing extensive marshes in the eastern portion of the lake, with subsequent restrictions concerning entry into these areas.

The tremendous annual increase of eastern red-wings leads to the view that the population may in time present serious hazards to area farm crops. Although the principal foods consist of weed seeds and insects, food habit studies have shown that red-wings frequently in-

vade fields of corn, wheat, and oats (Cardinell and Hayne, 1945). Because of the general tendency of small flocks to range long distances to feed, only slight damage may now occur in many fields and possibly goes unnoticed. However, considering the high rate of nesting success and low mortality rate of the young, it is felt that further studies will be necessary to determine whether management of the species is advisable.

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THE RANGE OF *ZOROTYPUS HUBBARDI* WITH AN ILLINOIS RECORD (INSECTA: ZORAPTERA)

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Specimens of the order Zoraptera are rare in collections, but one species, *Zorotypus hubbardi* Caudell, seems to be fairly abundant in at least parts of 17 southeastern states (Copeland, 1953, 1954; Riegel, 1950, 1956a, 1956b; Riegel and Koestner, 1957; St. Amand, 1954; Valentine and Wilson, 1949). Gurney's (1938) synopsis of the order listed *Z. hubbardi* from only seven states, with a doubtful record from Evanston, Illinois. Under the circumstances related by Dr. Gurney, it seems probable that the living specimens, found in a laboratory termite culture at Evanston, actually came from another locality.

The first *bona fide* Illinois specimens were taken from a sawdust pile at the Kelly Band Mill, Lawrenceville, on Sept. 15, 1956, by G. T. Riegel. Additional specimens were collected there on March 9, 1957, by Riegel and B. A. Landes, showing that this population had survived the winter successfully. When the latter collection was made the air temperature was slightly above freezing, yet the decaying sawdust was at 95° F. 18 inches below the surface where the specimens were found.

On May 12, 1956, numerous specimens, including one winged and one dealate female, were collected from sawdust near Montreal, Camden Co., Missouri, by Riegel, J. T. Fulton, Landes, J. T. McGinnis and R. W. Pippen. This extends the known range of *Z. hubbardi* approximately 115 miles northwest from a previous record (Riegel, 1956a).

On July 22, 1956, more than 100 additional specimens, including one winged female and many nymphs with long wing pads, were taken by E. J. Koestner and Riegel from a sawdust pile in Pike Co., Ohio, where the species had been collected earlier (Riegel, 1956b). These specimens (Dayton Museum of Natural History) are interesting in that they confirm Gurney's (1942) observation that winged forms occur throughout the summer.

The pattern of distribution that is emerging for *Z. hubbardi* seems to coincide with the deciduous forest region north almost to the 39th parallel. The known range now includes all eastern states south of this parallel, and west to and including eastern Texas, except Delaware, West Virginia, Kansas, and Oklahoma.

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MUCOSUBSTANCES IN PLAGIORCHOID AND MONOSTOMATE CERCARIAE (TREMATODA: DIGENEA)

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Introduction

The development, distribution, and function of a series of glands, highly metachromatic to thionin and toluidine blue O, have been described from the cercariae of various species of digenetic trematodes. The widespread occurrence of the glands indicates their importance in the economy of the parasites. The glands appear in all groups of xiphidiocercariae studied (Kruidenier, 1951, 1953) and in the notocotylid (monostome) cercariae (Kruidenier, 1953a).

Variation in the shape, distribution, and metachromasia of the glands was reported. Glands of the xiphidiocercariae were variably compact to diffuse in closely related species of cercariae. They were ventrally located and highly chromophilic. Glands of the notocotylids were dorsal to dorsolateral and varied from slightly irregular in *Cercariae Nudacotyle novicia* Barker, 1916, to pleomorphic but generally stellate in *C. urbanensis* Cort, 1914 (see Kruidenier, 1953a). The metachromasia of the notocotylids was less stable in the presence of alcohol than was that of analogous glands in the xiphidiocercariae.

Preliminary attempts by the senior investigator to demonstrate metachromatic glands in the cercaria of *Macravestibulum eversum* Hsü (Pronocephalidae) were unsuccessful. Further study resulted in their discovery. The glands are apparently not described for any of the pronocephalid cercariae. Preliminary observations demonstrated that the glands differed from those of xiphidiocercariae and the notocotylid species.

Acknowledgments

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Materials

Two species of virgulate cercariae, *C. geddesi* Ameel, 1939, from *Pomotiopsis lapidaria* (Say), and an undescribed species from *Goniobasis livescens* Menke included in the earlier study of virgulate cercariae were used in this investigation. One ornate species, *C. Macroderoides typicus* (Winfield, 1929) Van Cleave, 1932, from *Helisoma trivolvis* (Say), was used. An undescribed microcotylous species from *G. livescens*, also reported previously, was obtained. *C. urbanensis* Cort, 1914, from *Physa sayii* (Tappan), and *C. Macravestibulum eversum* Hsü, 1937, from *G.*

livescens Menke represented notocotylid and pronocephalid monostomes, respectively. All the above species were collected near Ann Arbor, Michigan. One armate species, tentatively identified as *C. Tetrapapillatrema concavocorpa* Sizemore, 1936, was obtained from *Helisoma trivolvis* (Say) collected in Urbana, Illinois.

Methods

Serial sections, of infected snails killed and fixed entire in Bouin's fluid, were used. Whole mounts were made of developing cercariae dissected from snails and fixed in corrosive sublimate. Serial sections and whole mounts were made of normally emerged cercariae fixed in corrosive sublimate and in alcohol-formalin. Bouin-fixed sections were occasionally mordanted in $HgCl_2$ for specific test purposes.

Metachromasia of glandular secretions was tested in 0.001 toluidine blue 0 (Allied Chemical and Dye Corporation, C.I. No. 925) buffered to pH values of from 1 to 6.4 with acetate buffer solutions. A model G Beckman pH meter was used. Sections were brought to water, placed in the appropriate buffered dye solutions for one hour, drained or blotted, and then rinsed for exactly five seconds in absolute ethyl alcohol and then cleared in xylol and mounted in H and R medium.

Metachromasia in alcohol was tested by the above procedure except that test solutions consisted of 0.001 toluidine blue 0 in 25%, 50%, 75% and absolute ethyl alcohol in distilled water at pH 6.5 to 7.

The Schiff reaction was performed on sections without prior oxidation (controls) and following oxidation with periodic (PAS) peracetic and chromic acids (Bauer) or with potassium permanganate (Casella). Sections were exposed to pyridine at 25°C. for 24 hours and to malt diastase at 40°C. for 1 hour before testing with periodic acid-Schiff procedures (PAS).

Every attempt was made to standardize the timing of the steps of the Schiff procedure. Exposure to leucofuchsin reagent was 15 minutes. Fresh solutions of oxidizer, iodide-thiosulfate reducing bath, and sulfite wash were used for each test. Sections were rinsed in the sulfite wash and then passed through a minimum of three successive changes for a total of six minutes. Critical test sections were washed thoroughly in running tap water before rapid dehydration. Fresh alcohols were used to prevent the leucofuchsin, which leaches into the solutions, from producing false reactions. Haematoxylin, fast green and, occasionally, orthochromatic methylene blue or toluidine blue (in absolute alcohol) were used as counter stains.

Whole mounts were prepared with dilute, aqueous thionin at approximate neutrality or by means of PAS procedure.

Mercury was removed with iodine solutions where necessary.

Observations

Virgulate xiphidiocercariae: Metachromasia in *C. geddesi* (Fig. 1) has not been described previously. It is similar to that of the other virgulates reported (Kruidenier, 1951). Present studies thus are supplementary.

Six pairs of metachromatic glands are visible in the developing, intraradial cercariae as the tail stem, oral sucker and ventral sucker differentiate. Glands reach maximal development when cercariae attain maturity within the rediae. Secretions are discrete droplets in young glands but coalesce into a single mass as they accumulate. The glands are aligned ventrally, on either side of the mid-line with three pairs anterior to the acetabulum, one pair at that level, and two pairs posterior to it.

Ducts from the anterior four glands have been traced to the level of the buccal cavity and from the third pair to the posterior border of the oral sucker. The fourth pair of ducts was traced mid-way between the suckers, and those from the posterior glands discharge on either side of the tail stem.

All glands discharge as cercariae reach maturity within the rediae. The virgula forms concurrently in the oral sucker and the periphery of the cercarial bodies become strongly metachromatic. Their tails are not metachromatic at any time. Small remnants of secretion remain in the glands and are visible in normally emerged cercariae (Fig. 1). Metachromatic layers are heaviest in areas adjacent to the pores of discharge.

The virgula resembles one of those previously described (Kruidenier, 1951:681, Fig. 20), appearing as swollen tubes coiled around the buccal cavity. Paired ducts open into the buccal cavity mid-way between the oral aperture and the esophagus. Strands of secretion commonly extend from the pores, convoluting extensively beyond the mouth. The adhesion of debris demonstrates the sticky nature of the strands. Appreciable loss in size during migration within the snails and after emergence attests to the constant discharge of virgular contents, but virgulae never discharge completely from free-living cercariae. Virgulae were not observed during cercarial penetration of second intermediate hosts.

A distinct cuticula is present prior to the discharge of metachromatic glands and the concurrent appearance of peripheral metachromasia.

The large ventral glands and the virgula show strong gamma metachromasy after treatment with toluidine blue at pH 1, and peripheral metachromasia is identical as it appears. Metachromasy increases to maximal violet to blue-black intensity with increased basicity of dye solutions. No other structures within the cercariae or rediae are metachromatic at the test levels and, at pH 1, only mucosubstances are chromophilic; all other tissues, cercarial and snail, remain unstained. Metachromasia is strong in 75% alcohol solutions of toluidine blue and roughly parallels that observed at high acid levels. Epithelial mucoid of the snail is metachromatic at these levels also and affords constant controls for many of the studies. Chromophilia of parasites and snail tissues increases with the basicity of the dye solutions. It becomes intense at pH 6.4 and in the absence of alcohol.

A very faint pink reticulum is variably present in the metachromatic glands and virgulae of some specimens treated with leucofuchsin after PAS, Bauer, and Casella procedures. The erratic reaction does

not intensify with 45 minutes of exposure to the leucofuchsin reagent. The counterstains used obscure all traces of the reaction. Hematoxylins stain the mucosubstances deeply.

Malt diastase or pyridine digestion do not affect the reactions. The activity of virgulae and peripheries remains identical after the emergence of the cercariae from snail tissues.

The formation and function of mucosubstances in the undescribed virgulate cercaria from *Goniobasis livescens* used in these studies have been detailed (Kruidenier, 1951: 680, Figs. 1-11; and 682, Figs. 28-32). The metachromatic and Schiff reactivity of ventral glands, virgulae and peripheral substances parallels that of the analogues of *C. geddesi* (*v. supra*).

NON-VIRGULATE XIPHIDIOCERCARIAE: *Armate.*—Metachromatic substances have not previously been described in the cercariae of *Tetrapapillatrema concavocorpa* Sizemore, 1936 (Fig. 4). This species generally resembles *C. isocotylea* (Cort, 1914), studied less intensively by Kruidenier (1953).

Six large glands develop on either side of the mid-ventral line and distribute as described for the analogues in *C. geddesi* (Figs. 2, 3). Glands first appear as diffuse metachromatic areas and attain maturity as cercariae reach maximal intraredial development. They do not branch profusely but do develop lateral processes which terminate in small temporary lateral reservoirs (Fig. 3). The ducts appear similar to those of *C. isocotylea* (Kruidenier, 1953). All of the glands discharge prior to cercarial emergence from rediae. Concurrently, caudal pockets enlarge and fill with secretions; the peripheries of the cercariae become highly metachromatic (*v. infra*). A cuticula is distinct around the cercariae before the glands discharge and peripheral metachromasia is acquired. The supracuticular layer is distinctly thicker at the extremities of the body. It is heaviest within the caudal pocket, although large deposits obscure this. Tails do not acquire surface metachromasia.

Ventral glands, caudal pockets and peripheries of respective cercariae are metachromatic (gamma) at pH 1 and above. Further, metachromatic and Schiff reactivity tests are also identical to those described herein for *C. geddesi.* Hematoxylin reacts strongly with the mucosubstances.

Ornate.—The gross metachromasy, glandular complex, caudal pocket and peripheral metachromasia (gamma) of the cercaria of *Macroderoides typicus* have been reported by Kruidenier (1953). In the present differential tests the metachromatic substances show strong gamma metachromasia at the pH 1 to 6.4 levels tested and in concentrations of alcohol to 75%. Metachromatic substances are negative to PAS, Bauer, and Casella tests and are not affected by exposure to malt diastase and pyridine. Hematoxylin reactions are strong.

Microcotylous.— An undescribed species of microcotylous cercariae was discussed by Kruidenier (1953: 386, Figs. 23-24). Further studies demonstrate that the ventral metachromatic glands and peripheral substances develop increasingly strong gamma metachromasia at pH levels from 1 to 6.4 at alcohol concentra-

FIG. 1.—*Cercaria geddesi*, emerged, $HgCl_2$ thionin, X500 (approx.); Figs. 2-4.—*C. Tetrapapillatrema concavocorpa*, developing (2, 3) and emerged (4), $HgCl_2$, thionin, X 250 (approx.); Figs. 5-7.—C. *Macravestibulum eversum*, developing (5, 6) and mature (7), $HgCl_2$, PAS, X150 (approx.) Mucosubstances (Figs. 1-7) and eyespots (Figs. 5-7) are black.

tions to 75%. PAS, Bauer, and Casella tests are negative and reactions are not affected by malt diastase or pyridine extraction.

MONOSTOME CERCARIAE: *Notocotylidae.*—Details of the development, morphology, and fate of the metachromatic glands of *C. urbanensis* Cort, 1914, have been reported (Kruidenier, 1953a). Glands are included within the oral suckers, along the dorsa of the cercariae, associated with the locomotor organs, and in the tails. They stain deeply with hematoxylin.

The metachromatic reaction of the stellate body glands of *C. urbanensis* contains a considerable blue-black element which produces a net result of red-purple to violet. Secretions are coarsely granular but a homogeneous substrate is also apparent. Granules develop beta metachromasy while the substrate shows clear red or gamma metachromasia. The secretions of the glands within the tails are homogeneous.

Stellate and tail glands of *C. urbanensis* are orthochromatic at pH 1.5 and metachromatic at pH 2.5 to 3 and above. Granular contents of the stellate glands are beta metachromatic, substrates are gamma. Metachromasia develops in 0 to 50% alcohol. The glands within the oral suckers are faintly metachromatic at pH 3.8 and above. Glands of the locomotor organs are metachromatic at pH 3 and above. Peripheral metachromasia appears as stellate body glands discharge and parallels the acid and alcohol levels of these glands; it is restricted to dorsal and dorso-lateral surfaces. The granules (beta metachromatic) persist as distinct entities after cercarial emergence. Extraction with pyridine and digestion with malt diastase do not change the metachromatic levels of any of the glands. Prior treatment with $HgCl_2$ does not affect the metachromatic reactions.

Stellate body glands and tail glands are variably PAS positive. The reaction is strong in younger cercariae but it weakens and becomes restricted to a faint reticulum in nearly mature specimens. Granular secretions are not visible in the PAS preparations. A concentration of PAS positive material against the cell membrane of the glands may be a fixation artifact. Bauer and Casella reactions parallel the PAS reaction but appear generally weaker. The peracetic-Schiff reaction is negative. Malt diastase or pyridine do not the metachromatic reactions.

Glands within the oral sucker and those of the locomotor organs are strongly PAS, Bauer, and Casella positive throughout their history. They are peracetic-Schiff negative and their reactions are not changed by pyridine or malt diastase.

Pronocephalidae.—The trioculate cercaria of *Macravestibulm eversum* possesses 11 pairs of pleomorphic body glands whose numerous stellate processes branch irregularly (Figs. 5, 6). The glands grossly resemble their analogues in *C. urbanensis* but remain smaller.

Six pairs of glands distribute symmetrically on either side of the mid-dorsal line. The anterior pair is obscured by the dorsal, pigmented eye spots. Branches from the posterior pair extend almost to the posterior limits of the body. Eight glands align bilaterally along the dorso-lateral body margins from the

level of the eye spots to the posterolateral body curvatures. A single stellate gland is closely associated with each locomotor organ. The tail of the cercaria contains 10 pairs of irregular glands. The secretions of all the glands appear homogeneous.

The glands appear after the differentiation of the tail, oral sucker, and lateral eye spots (Fig. 5). *C. eversum* develops considerably after discharge from rediae into snail tissues (see also Hsü, 1937). The glands of the cercariae develop largely during extra-redial phases of embryology (Figs. 5, 6). Glands discharge completely as the cercariae finally mature (Fig. 7) and a fine granular film of their secretion distributes over the entire periphery of the cercariae during their later development. A distinct cuticula is readily visible prior to the appearance of secretions at the periphery. The granules lose their identity as the film becomes a homogeneous layer.

Body and tail glands are hematoxylin-positive and metachromatic at pH 3.8-4. Peripheral metachromasy reacts identically. Metachromasia tends towards the violet (beta) range. Tail and locomotor glands appear distinctly redder. The description of the former glands as beta metachromatic, however, may overemphasize the slight differential reaction.

All glands and the peripheral substances are uniformly and strongly PAS positive. Bauer and Casella tests are weaker. Peracetic-Schiff tests are negative. Malt diastase and pyridine do not visibly affect the reactions. The cuticula is thick and it is weak to negative after the PAS reaction.

Discussion

The full significance of the phenomenon of metachromasia remains unclear despite the numerous competent investigations since its discovery by Jurgens (1875). It is not possible to review the investigations here but several pertinent facts should be presented.

Pischinger (1925) associated the pH level of metachromasia with the isoelectric points of the different compounds. Bank and Bungenberg DeJong (1939) believed the reaction dependent on the charges of colloid ions and the type of ion grouping produced by reactants. They found sulfate, phosphate, and carboxyl colloids to be metachromatic. Dempsey and Singer (1946) considered that treatment with mercuric salts destroyed or suppressed the metachromatic reactivity of carboxyl radicals.

Lison (1936) presented evidence that metachromasy, obtained under conditions of rigorous alcoholic dehydration, identifies high molecular weight sulfuric esters of mucosubstances. Freyrter (1936) demonstrated metachromasia in myelin sheaths; Meyer (1946) noted a lytic action by hyaluronidase on ganglia of tendon sheaths, and Altschuler and Angevine (1949) reversed myelin metachromasia with hyaluronidase. Pearse (1954) felt that sheath metachromasia is possibly due to phosphate moieties.

Michaelis and Granick (1945) suggested the formation of thiazine dye polymers with varying substrates. Thus, an alpha monomer (blue), a beta dimer (violet) and a gamma polymer (red) are possible. Michae-

lis (1947) found that highly polymerized carbohydrates (carboxyl groups) alone can induce metachromasia.

Pearse (1954) believed that water must be present to produce the reversal of metachromasia to orthochromasia noted above.

Thus, numerous compounds may produce metachromasia under different conditions but it seems most probable, at present, that gamma metachromasia at high alcohol or acid levels differentiates acid mucopolysaccharides containing sulfuric esters. Lesser metachromasia indicates phosphate esters, hyaluronic acids, and/or neutral mucopolysaccharides.

In the present tests metachromasia was graded under rigidly controlled schedules and at varying acid and alcohol levels, but it is obviously not possible to identify specific substrates from this. Gamma metachromasy at levels below pH 4 indicates acid mucopolysaccharides and at pH 2 or below almost certainly indicates sulfuric esters. High resistance to alcoholic reversal most probably confirms the latter. Metachromasy bordering the beta type at pH 4 or slightly less would characterize more weakly acid compounds such as the neutral mucopolysaccharides or mucoproteins. It might also indicate lower molecular weights of substrate complexes or, simply, "smaller" compounds.

It seems to us that beta metachromasy might also indicate carbohydrate-protein ratios. Protein complexes are orthochromatic. Variable combination with blue monomers of the thiazines would proportionally dilute the gamma metachromasy attributable to given sulfuric esters of hexose compounds.

The Schiff reaction usually demonstrates 1:2 glycol groups when oxidation is effected with periodic or chromic acids or with permanganate. Compounds which can produce the reaction include glycogen, mucopolysaccharides, muco- and glycoproteins, glycolipids, phospholipids, and even unsaturated lipids (—C=C—). It is essential to control the reaction with pyridine extraction (removal of known lipids, malt diastase (glycogen), and peracetic oxidation (unsaturated lipids).

Bauer and Casella reactions further characterize Schiff positive substances. In the present studies the Casella reactions were occasionally inconsistent but less so when fresh solutions were used. Removal of excess permanganate appears to be the major problem.

Conclusions

The metachromatic level of the glands of *C. eversum* indicates the presence of relatively less acid mucoproteins but does not clearly demonstrate the neutrality of the compounds. Darker metachromasia may well indicate a higher protein content of the substrates as well as more weakly acidifying esters (*e. g.*, phosphate). The homogeneous secretions possess oxidizable 1:2 glycols.

The metachromasia of the glands of *C. urbanensis* is intermediate between those of the xiphidiocercariae and of *C. eversum* in acid-base and alcohol stainability levels. The closer relationship to *C. eversum* reactions is emphasized by the metachromasy of the monostomates at lower test levels. The tests may roughly in-

dicate relative protein content and are a measure of the relative molecular acidity of the metachromatic complexes. Their reaction cannot be attributed to carboxyls because it was not affected by prior exposure to mercuric salts ($HgCl_2$) which destroy the metachromatic reactivity of such groups (Demsey and Singer, 1946).

The glands within the oral sucker and those associated with the locomotor organs of *C. urbanensis* differ from the stellate body glands and the tail glands of that species. Persistent oxidizable 1:2 glycols are not present in the final, definitive secretions of stellate and tail glands (PAS negative). They are lightly but distinctly orthochromatic at pH 1.5 whereas sucker and locomotor glands are not chromophilic at this level. The lower acid dissociation level of the latter appears to be limited to approximately pH 3. They thus approach the weakly acid to neutral mucopolysaccharide or mucoprotein reactions (+pH 4).

Sulfate ions dissociate at values far below pH 4 and are therefore indicated by the chromophilia of the stellate and tail glands. Their orthochromasia at pH 1.5 may indicate a relatively high molecular protein component. This is more certain because compounds with relatively high carbohydrate-sulfuric moieties (*e. g.*, chondroitins and mucoitins) would show the gamma metachromasy observed in the epithelial mucoids (snail) present in the sections. Metachromasia at pH 2.5-3 indicates sulfuric esters. The secretions of matured glands therefore appear to be highly saturated hexose sulfuric esters of large protein complexes.

The orthochromasia of the granules within the stellate cells of *C. urbanensis* at pH 1.5, and the failure of their homogeneous substrate to stain at this level, indicate that these are chemically different substances. This is confirmed by the beta metachromasia of the granules and the gamma metachromasia of the substrates in identical glands at the same pH levels (2.5 and above). The use of both substances in the formation of the metachromatic peripheral film indicates that they are end products of the glandular secretory activities.

The change during the development of the glands from a strong to weak or negative PAS reactivity is confined to the substrate. Both end products are negative. It is reasonable to assume that the early, PAS positive substances contribute to the formation of the granular and the homogeneous secretions. Synthesis in the glands thus appears to include esterification of the glycol radicals. The unchanged metachromasia of the substrates, in the tests performed, indicates the maintenance of roughly the same carbohydrate - ester - protein ratios in their molecular constitution. Changed metachromasia in the granular secretions, and their increased orthochromatic chromophilia, indicate appreciable increments of protein complexes. Thus, the synthesis of the secretions appears to involve the protein esterification of polysaccharide materials.

The reactions are remarkably uniform within the xiphidiocercariae. It does not seem probable that the metachromatic complexes studied in

the different species of these cercariae are chemically identical. It does seem probable that their physical characteristics are similar (Kruidenier, 1951, 1953) and that certain fundamental chemical features are common to them. The mucosubstances are almost certainly sulfuric ester mucopolysaccharides. They lack 1:2 glycols, an indication of the high saturation of their carbohydrate moieties. Difficulties with the permanganate reagent of the Casella test may indicate particular or considerable combining characteristics under specific conditions not clearly understood. Basic chemical and physical similarities imply similar uses of the secretions. Further study is needed to explore this possibility.

The metachromatic and Schiff techniques demonstrate a decided difference between the mucosubstances of plagiorchoid and monostomate cercariae. The latter are measurably less resistant to the repressant effects of acidity and alcohol. They thus appear to be less highly acid and nearer the level of neutral mucopolysaccharides or mucoproteins. It is interesting that the variation is grossly group consistent and accompanies a phylogenetic differentiation which also includes marked life history differences. The plagiorchoids use insects (naiads for known virgulate species) and tadpoles (*C. typicus* and *C. concavocorpa*) as intermediate hosts. The monostomates encyst on detritus (*C. urbanensis*) or on specific surfaces such as snail opercula (*C. eversum*). Minor differences also accompany the variation between monostomates. Lesser metachromasia and greater Schiff reactivity appear to correlate with the specific use of snail opercula (*C. eversum*). However, it would be unjustified to generalize widely in the absence of more complete data.

A cuticula can be distinguished prior to the discharge of mucosubstances in all of the species of cercariae studied. It is differentiated as a distinct layer, less reactant (or negative) to the differential techniques used, and immediately beneath the sheath of mucosubstances which forms around mature cercariae. No structural separation of the two layers is visible. It is possible that the metachromatic or the PAS positive substances combine chemically with the cuticula at the interface. Individual layers thus would retain their chemical identity, as observed, and, presumably, their physical characteristics.

The mechanics of the actual distribution of the peripheral substances have been discussed by Kruidenier in previous reports concerning various groups of cercaria. The differential distribution on the cercariae studied here appears to correlate superficially with the loci of glandular discharge. Thus, mucosubstances are more abundant ventrally and over the anterior and posterior surfaces of xiphidiocercariae. The caudal pockets of armate and ornate species are lined by the heaviest permanent layers of metachromatic materials, although this is more difficult to determine because of the masses of the secretions that are stored within the pockets. The ventral surface of *C. urbanensis* is non-metachromatic.

The absence of a peripheral layer

from the tail surfaces of the xiphidiocercariae may indicate that mucosubstances do not reach the surfaces of the tails. This is in accord with the absence of glands from the tails, and with the presence of such glands as well as the deposition of a surface coating in the monostomate species. It is especially difficult to understand how mucosubstances fail to reach any part of the tail of *C. concavocorpa* when the base of the tail in this species attaches to its body literally within the caudal pocket itself. The formation of the caudal pocket late in the development of the cercariae (Hussey, 1941) and its final enlargement during the discharge of the posterior mucoid glands of the cercariae (Kruidenier, 1953) may be an important factor in this phenomenon. Investigations in progress may explain more fully the relation of peripheral mucosubstances to the cuticula of cercariae. Certainly present data are insufficient.

Summary

Brief descriptions are presented of the development and fate of previously unreported mucoid glands in *Cercaria geddesi* and *C. concavocorpa* (virgulate and armate xiphidiocercariae, respectively) and *C. eversum* (pronocephalid monostome). The glands of these species and of a second, undescribed virgulate cercariae, an undescribed microcotylous species (xiphidiocercaria), *C. typicus* (ornate xiphidiocercariae) and *C. urbanensis* (notocotylid monostome) are studied. These investigations amplify our knowledge of the distribution of the mucoid glands in xiphidiocercariae and extend it to the family Pronocephalidae of the monostomes.

The metachromatic and Schiff reactivity of the glands of the above species are analysed under controlled but varied conditions. The detailed analyses provide information pertaining to a more precise chemical nature of the mucosubstances studied and suggest certain sequences in the syntheses of the compounds. The tests make it possible to compare fundamental differences in the secretions produced by the various species of cercariae.

Factors in the relation of the discharged mucosubstances to the cuticula of the cercariae are suggested but demand further clarification.

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THE FIRST RECORDS OF BOREUS (BOREIDAE, MECOPTERA) IN ILLINOIS

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The insect genus *Boreus* is peculiar in many ways. It belongs to the odd order called Mecoptera. Characteristically, members of this order have a long mouth cone, flimsy wings with primitive venation, and long slender legs. Some Mecoptera are known as scorpion-flies because the males have upturned claspers borne at the end of a slender, drawn-out abdomen which, when carried high, resembles the stinger of a scorpion. Other Mecoptera look like craneflies. But *Boreus* is unlike either of these types. In members of this genus the wings are reduced to modified pads and the abdomen is short (Fig. 1). Furthermore, *Boreus* is not active as an adult in summer as are other Mecoptera; instead, *Boreus* comes out from December to March, or earlier or later in the western mountains.

FIG. 1.—*Boreus brumalis* Fitch, lateral view, adult. (Photograph by William E. Clark, Illinois Natural History Survey.)

As the name implies, *Boreus* is a genus of boreal or northern insects. Species are found in northern Europe and northern North America. In North America their ranges extend southward primarily in mountains such as the Sierras, Rockies, and Appalachians.

In the eastern half of the United States, two species are known. *Boreus nivoriundus* Fitch, the larger of the two, occurs from Maine south to the Great Smoky Mountains National Park and west to Ohio (Byers, 1954). The other species, the tiny, black *Boreus brumalis* Fitch, has been reported from Massachusetts, New York, District of Columbia, Tennessee (Great Smoky Mountains), Ohio, and Michigan (Byers, 1954), and from Pennsylvania (Frost and Brown, 1957).

The occurrence of *B. brumalis* in Illinois is here reported for the first time. These records constitute the most western localities. Originally this species was taken in Illinois by Drs. H. H. Ross and M. W. Sanderson in 1943 at Fountain Bluff, near Gorham. They discovered a single larva (Fig. 2) in a sample of debris

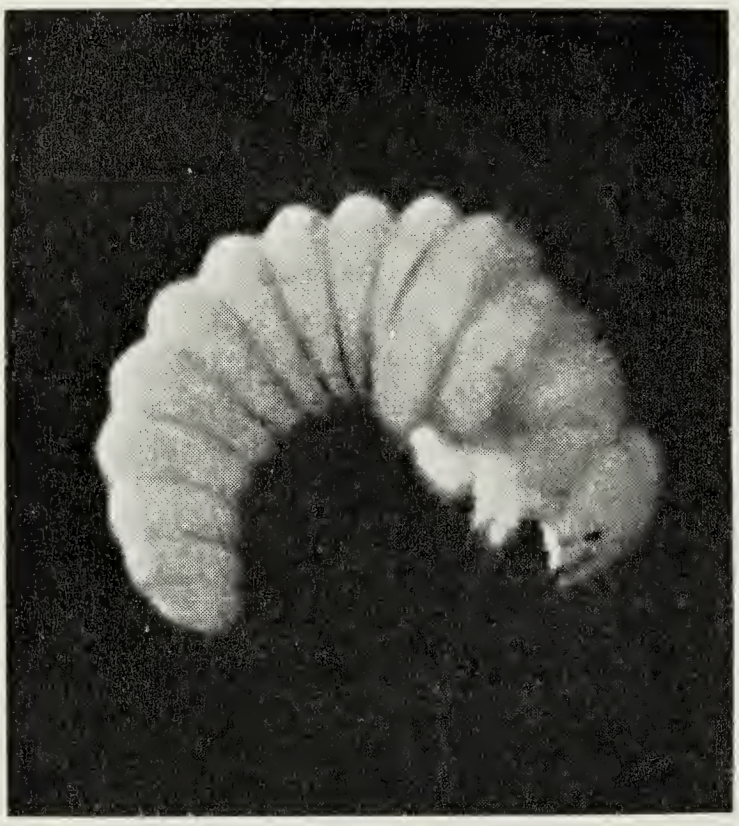

FIG. 2.—*Boreus brumalis* Fitch, larva. (Photograph by William E. Clark, Illinois Natural History Survey.)

gathered from the edge of a rotten log. Other larvae and adults were subsequently found in three southwestern counties, Alexander, Union, and Jackson. Despite repeated attempts to collect this insect from moss and forest debris gathered from spring to fall throughout the state and from numerous searches on snow and mossy hillsides in winter in much of Illinois, *B. brumalis* has not been found outside the southwestern part of the state.

In New England and other eastern states, including eastern Michigan, *B. brumalis* often inhabits areas formerly covered by Pleistocene ice sheets. In Illinois, however, its range appears not to extend into terrain that was formerly glaciated. By way of speculation it may be that this species occurs in Illinois as a relict of ancient mesophytic forests, forests which are still tenuously connected to the Appalachian and Cumberland remnants through Kentucky but which have not completely reoccupied glaciated territory in the midwest. That *B. brumalis* is probably not a glacial relict is indicated by its absence in northern Illinois where other glacial relicts, such as *Cottus* and tamarack, still persist.

NEW RECORDS OF *Boreus brumalis* FITCH IN ILLINOIS

JACKSON COUNTY:—1 larva, Fountain Bluff (near Gorham), March 18, 1943, Ross and Sanderson, around rotten log; 2♀, 2♂, Fountain Bluff (near Gorham), February 13, 1957, Ross and Stannard, on moss; 6 larvae, Cora, March 12, 1946, Ross and Burks, in moss. UNION COUNTY:—2 larvae, Alto Pass, March 13, 1946, Ross and Burks, in moss; 6♀, 5♂, 11 larvae, Alto Pass, January 25, 1947, Burks, Riegel, and Stannard, in moss. ALEXANDER COUNTY:—2 larvae, Thebes, April 19, 1944, Ross and Sanderson.

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NORTH AMERICAN *STENUS* OF THE *ADVENUS* COMPLEX INCLUDING A NEW SPECIES FROM ILLINOIS (COLEOPTERA: STAPHYLINIDAE)

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The North American species of *Stenus* are assignable to five or six subgenera primarily on the basis of the bilobed or unmodified fourth tarsal segment and the presence or absence of a lateral margin or suture on each of the abdominal segments. The subgenus *Hypostenus* Rey (1883:183) included those species having the fourth tarsal segment bilobed and the abdomen unmargined. Apparently unaware of the earlier description of *Hypostenus,* Casey (1884:150) proposed the new genus *Areus* to include species now known to have *Hypostenus* characteristics, and he also included in *Areus* four species having the abdomen margined. These four species have been referred to the subgenus *Hemistenus* by Sanderson (1946).

Within the subgenus *Hypostenus,* as now restricted, are 37 species considered by Casey (1884) in a revision of the Stenini. Through the courtesy of the United States National Museum I was permitted to examine the Casey types of these species in June of 1955. My findings regarding *advenus* Casey and two closely related species constituting the *advenus* complex are included in the present report.

Several institutions and individuals have provided collections of *Stenus* in the *advenus* complex for my study as follows: Canadian National Collection (CNC); University of Kansas (KU); M. H. Hatch (MHH); University of Alberta (UA); J. B. Wallis (JBW); Owen Bryant (OB); Borys Malkin (BM); A. Robert (AR); and C. H. Seevers (CHS). In addition to acknowledging this aid, I am grateful also to Mr. Bill M. Woods, map librarian of the University of Illinois, for locating several obscure place names.

Definition of the *advenus* Complex

Stenus advenus and its two close allies may be distinguished from other North American members of the subgenus *Hypostenus* by the following combination of characters: body and legs black, shining; first antennal segment black, and remaining segments dark brown; first segment of maxillary palpus pale yellow, and last two segments brown; pronotum shorter than elytral suture; first five segments of abdomen parallel or fourth and fifth segments often enlarged and wider than anterior segments; each of first five abdominal tergites conspicuously transversely grooved and obscurely finely punctured; sternite 7 of male narrowly and shallowly emarginate at middle of posterior

margin and with small group of short depressed hairs on each side of emargination; sternite 8 of male (Fig. 1) deeply and narrowly emarginate; sternite 9 deeply emarginate apically; and male genitalia with a bilobed process arising from ventral surface of aedeagus.

Key to Species of the *advenus* Complex

1. Penultimate abdominal sternite (Fig. 1) with deep and narrow emargination on posterior margin, males 2
   Penultimate abdominal sternite rounded at apex, females 4
2. Posterolateral margin of abdominal tergite 9 (Fig. 2) broad at apex, having two marginal projections; aedeagus (Fig. 7) short .... *advenus* Casey
   Posterolateral margin of abdominal tergite 9 (Figs. 3 and 4) narrowed at apex, having single marginal projection; aedeagus (Figs. 5 and 6) elongate 3
3. Marginal projection of tergite 9 (Fig. 3) less slender; paramere (Fig. 6) nearly parallel in apical one-half, apex obliquely truncate; aedeagus bluntly rounded at apex ..... *plicipennis* Casey
   Marginal projection of tergite 9 (Fig. 4) more slender; paramere (Fig. 5) with broad inner lobe near apex, and apex deeply obliquely emarginate; aedeagus constricted posterior to slender apex ..... *rossi* n. sp.
4. Pronotum and elytra finely, evenly, and closely punctured; head narrow, elytra varying from 1.32 to 1.38 times wider than head (17 specimens), averaging 1.36 times ..... *advenus* Casey
   Pronotum and elytra generally more coarsely and irregularly punctured with some conspicuous wide and shining inner spaces; head broader, elytra varying from 1.12 to 1.30 times wider than head... 5
5. Apical part of posterolateral margin of tergite 9 more slender, somewhat as in male in Fig. 4; elytra varying from 1.18 to 1.30 times wider than head, averaging 1.24 times; chiefly northeastern in distribution.....*rossi* n. sp.
   Apical part of posterolateral margin of tergite 9 less slender, somewhat as in male in Fig. 3; elytra varying from 1.12 to 1.25 times wider than head, averaging 1.19 times; chiefly northwestern in distribution .....*plicipennis* Casey

Stenus advenus Casey

Areus advena Casey, 1884:158.

Casey distinguished *advenus*, from all other Nearctic species having the fourth tarsal segment bilobed and the abdomen unmargined, by the enlarged fourth and fifth abdominal segments of the male. Some individuals of *rossi* also have these segments enlarged; thus, this feature alone will not serve to distinguish these two species. Ratios of head width to elytral width in 11 individuals showed that the elytra in *advenus* vary from 1.32 to 1.38 times the head width, averaging 1.36 times, whereas the elytra of *rossi* average 1.24 times the head width. Another distinctive feature of *advenus* is the presence of two acute angles on the posterolateral margin of tergite 9 (Fig. 2) instead of one angle as in *rossi*. The male genitalia of *advenus* also are distinctive, the aedeagus (Fig. 7) being much shorter than in *rossi* or *plicipennis*. The paramere is slender as in *plicipennis*, but it has the outer margin distinctly scalloped.

The range of *advenus* (Fig. 9) generally is within the range of *rossi*, and the two species are sympatric in two known localities. In addition to the type male from Marquette, Michigan, I have examined 17 specimens from the following localities: Victoria Beach, Manitoba (JBW); Brome Lake and Kazubazua, Quebec (CNC); Rigaud,

Quebec (AR); Cumberland Co., Maine (CHS); and Douglas and Lancaster lakes in Cheboygan Co., Michigan. A Douglas Lake specimen was collected at the edge of an inland pool. Dates of collection ranged from May 24 to August 18.

Stenus rossi new species

Male.—Length 4.0 to 4.5 mm.; dorsum shining, coarsely and somewhat irregularly punctured; head narrower than elytra, with punctures closely and evenly spaced, and median ridge broad and not strongly convex; pronotum about four-fifths as long as elytral suture, with length and width of pronotum approximately equal; lateral margin of pronotum concave between middle and base, with anterior two-thirds of dorsal surface even, and posterior third with conspicuous punctureless tubercle on each side of meson which has punctures more widely spaced than on sides; mean width of elytra 1.04 times mean total length (10 individuals, Alberta), and 1.24 times mean width of head (21 individuals, Illinois, Michigan, Alberta); elytra as coarsely punctured as pronotum and with some punctures more widely spaced than others; first five visible abdominal segments parallel or fifth visible segment wider than preceding ones; tergite 9 (Fig. 8) slightly emarginate at apex, inner side of this emargination with two widely spaced tubercles; posterolateral margin of tergite 9 (Fig. 4, arrow) very long and slender, approximately three-fourths length of apical flap of tergite 9; sternite 7 with slight emargination on posterior margin at middle, and with small group of coarse hairs on each side of emargination; sternite 8 widest about middle, narrowly and deeply emarginate (Fig. 1); sternite 9 deeply emarginate, truncate on posterior margin, with apical angles long and acute, each about one-half length of space between angles; aedeagus (Fig. 5) elongate, narrowed from base, slightly constricted posterior to the slender apex; paramere with broad inner lobe near apex, and apical margin deeply emarginate.

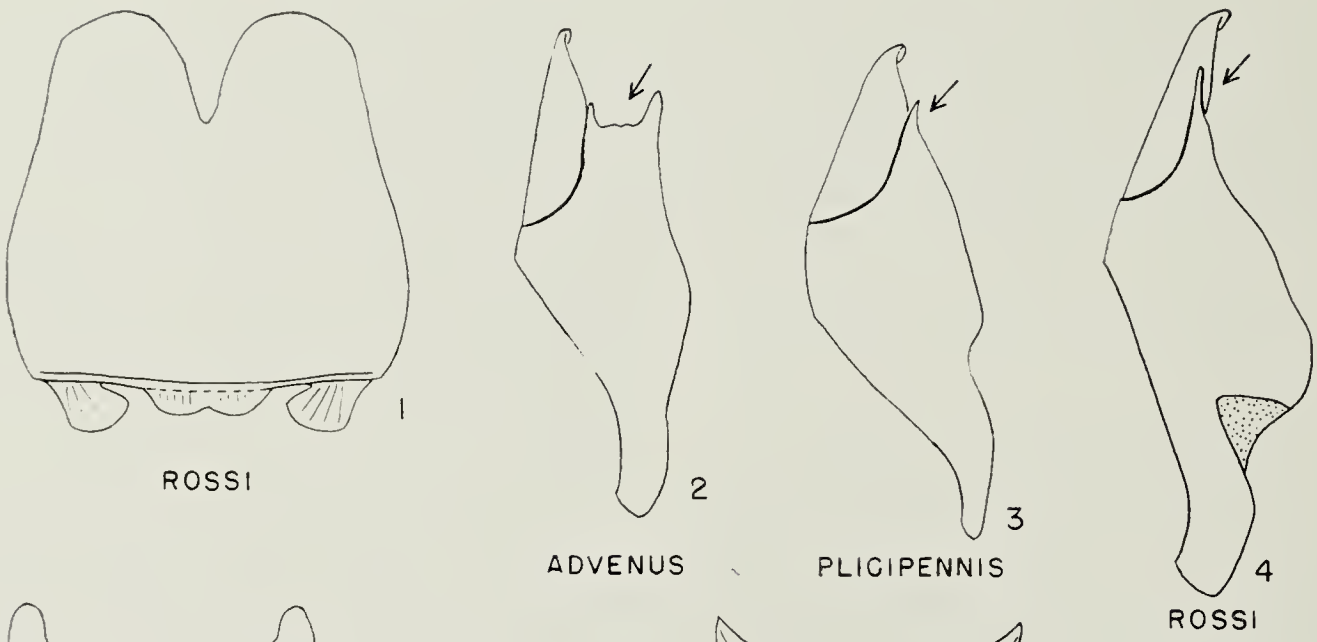
Female.—Similar to male except that fifth visible abdominal segment never wider than anterior segments, and apical flap of tergite 9 without tubercles on inner surface near apical emargination.

Holotype.—Male, Cary, Lake Co., Illinois, May 19, 1944, Ross and Sanderson, in marshland. *Paratypes.*—Same date, 3 males, 4 females; same data, except June 11, 1943, 1 female; Fox Lake, Lake Co., Illinois, June 3, 1943, Ross and Sanderson, 1 female. MICHIGAN: Burt Lake, Cheboygan Co., June 30, 1935, M. W. Sanderson, in lake drift, 1 male; Cheboygan Co., July 18, 1940, R. I. Sailer, 1 male (KU); Oakland Co., July 4, 1923, M. H. Hatch, 1 male (MHH). VERMONT: Burlington, Chittenden Co., April 20, 1952, F. R. Watson and F. G. Werner, in debris and leaf axils of *Cyperus*, etc. in pond, 3 males, 14 females. QUEBEC: Kazubazua, June 6-10, 1927, W. J. Brown, 2 males, 1 female (CNC); August 18, 1927, W. J. Brown, 1 female (CNC); August 28, 1928, J. A. Adams, 1 female (CNC). ONTARIO: Mer Bleue, June 1, 1928, W. J. Brown, 1 male (CNC); E. Ont., 1886 and 1887, 2 females (CNC). ALBERTA: Bilby, June 24, 1924, O. Bryant (OB); Edmonton, various dates from May to August, 1917 to 1924, F. S. Carr, 10 males, 16 females (UA). MANITOBA: Winnipeg, June 28, 1924, J. B. Wallis, 1 female (JBW); same data, except June 22, 1924, 1 female (JBW); same data, except July 6, 1924, 1 female (JBW); Aweme, July 29, 1924, J. B. Wallis, 1 male (JBW); Niverville, July 1, 1924, J. B. Wallis, 2 males (JBW); Stonewall, May 25, 1919, J. B. Wallis, 5 males, 3 females (JBW); Rosebank, July 21, 1917, J. B. Wallis, 1 male (JBW); Onah, July 11, 1918, J. B. Wallis, 1 male, 1 female (JBW); and May 24, 1912, J. B. Wallis, 1 male (JBW).

Type and paratypes are in the Illinois Natural History Survey Collection.

This species is named in honor of Dr. H. H. Ross who introduced me to the marshes of northern Illinois, the habitats of many species of *Stenus*.

The presence of a pair of tubercles on the inner surface of tergite 9 at the apex of the apical flap, the more produced posterolateral margin of tergite 9, and the large inner lobe on the paramere will distinguish *rossi* from the closely related *plicipennis*. Except for two isolated records of *rossi* from Alberta, all



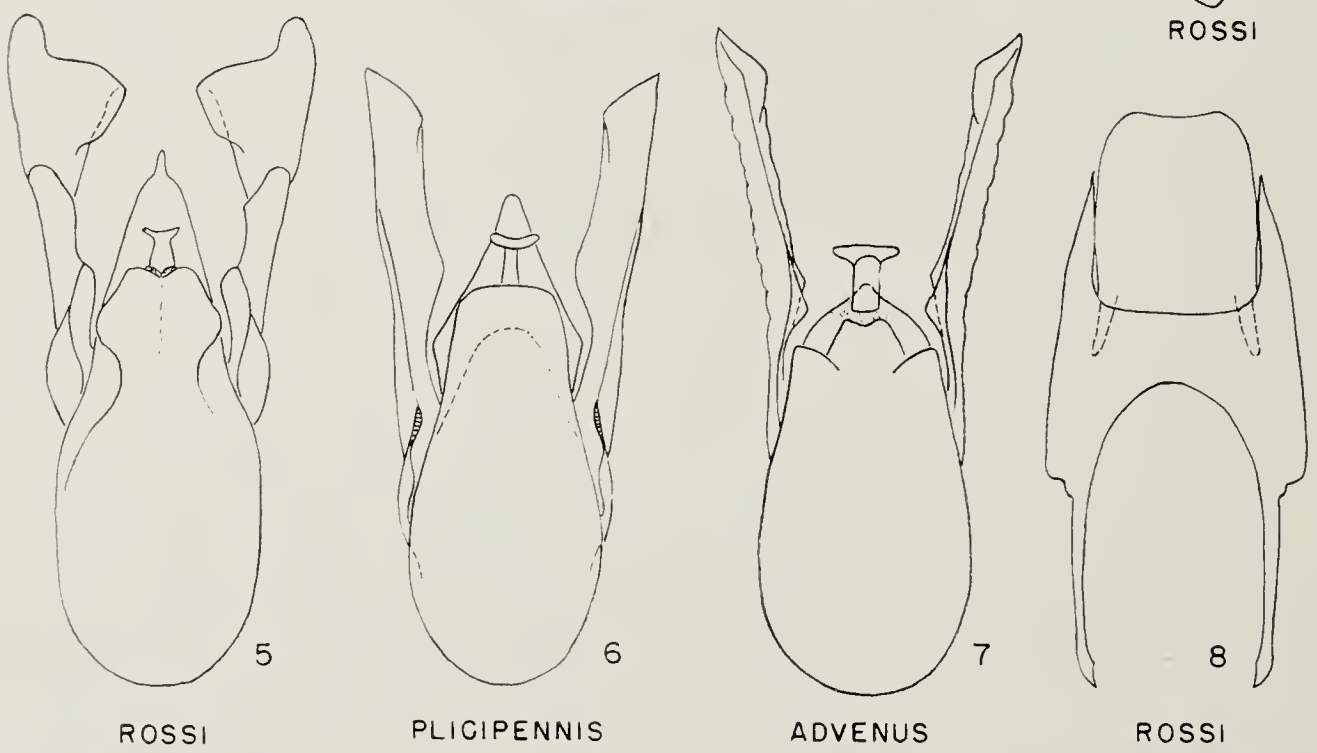


FIG. 1.—*Stenus rossi* n. sp., sternite 8, male; FIG 2.—*Stenus advenus* Casey, lateral view, abdominal segment 9, male, including apical jointed flap and posterolateral margin showing two acute apical projections; FIG. 3.—*Stenus plicipennis* Casey, lateral view, abdominal segment 9, male, showing one acute projection; FIG. 4.—*Stenus rossi* n. sp., lateral view, abdominal segment 9, male, showing one acute projection; FIG. 5.—*Stenus rossi* n. sp., ventral view, male genitalia; FIG. 6.—*Stenus plicipennis* Casey, ventral view, male genitalia; FIG. 7.—*Stenus advenus* Casey, ventral view, male genitalia; FIG. 8.—*Stenus rossi* n. sp., dorsal view, abdominal segment 9, male.

other specimens have been taken east of the 100th meridian; most *plicipennis* records are west of this line.

Stenus plicipennis Casey

Areus plicipennis Casey, 1884:162.
Areus agnatus Casey, 1884:163. New synonymy.

Casey described *plicipennis* from specimens of both sexes taken on Vancouver Island, B. C., and *agnatus* from the female collected in British Columbia. The latter was distinguished from *plicipennis* by the prominent anterior angles of the pronotum and the longer elytra. In the Fall River meadow marsh in Rocky Mountain National Park, Colorado, on September 11, 1954, I collected two males and four females of *plicipennis*. One female has

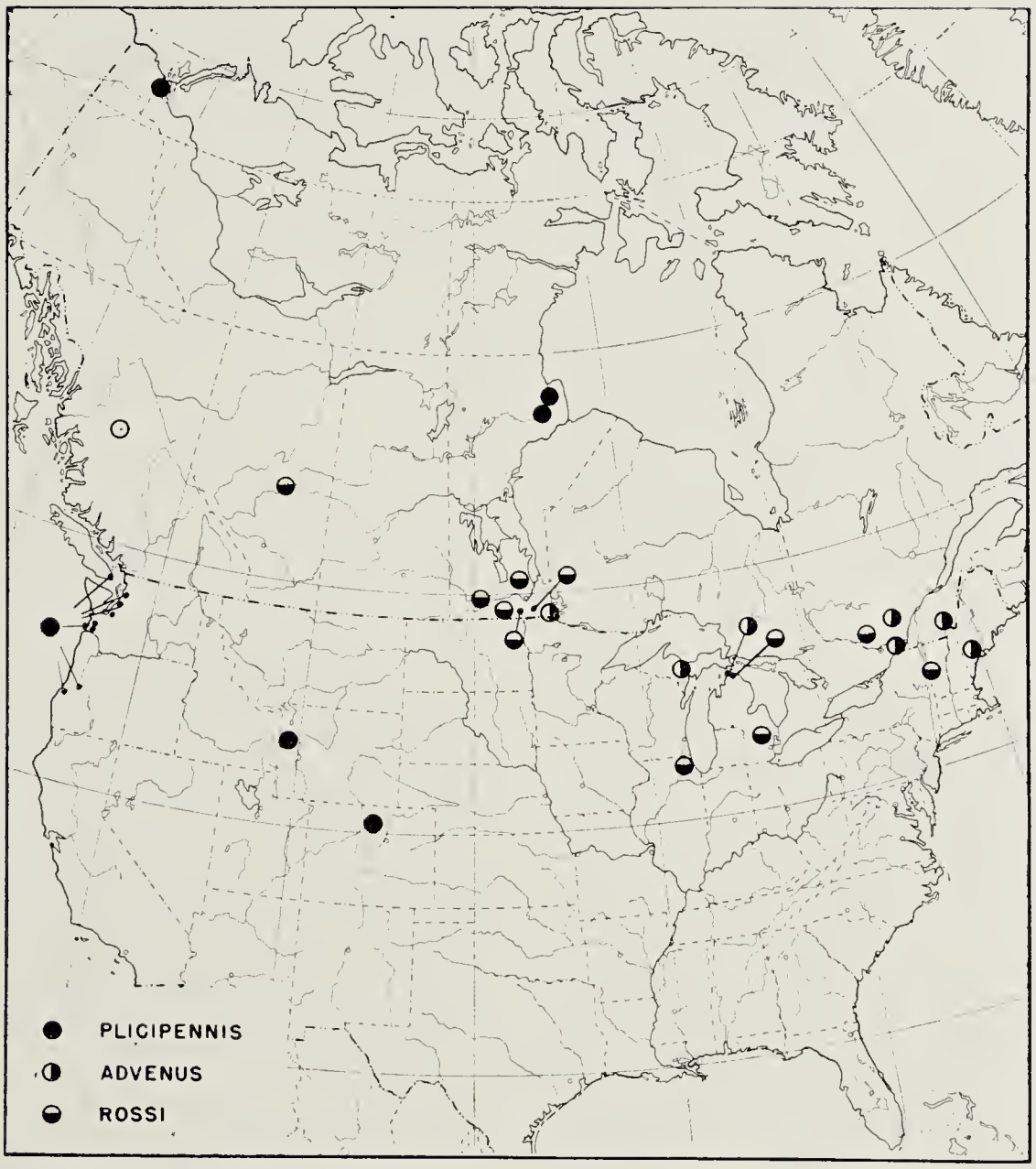


FIG. 9.—North American distribution of three species of *Stenus*. Open circle in British Columbia denotes province record only for *plicipennis*.

a small tubercle at the anterior lateral pronotal margin or angle and was found to agree favorably with the type of *agnatus*. The remaining females and males from Colorado, and a female collected in the elk range marsh two miles north of Jackson, Wyoming, September 3, 1954, essentially agree with the type of *plicipennis;* thus the presence of tubercles probably is atypical.

The individuals from Colorado and Wyoming and one male each from Mile 214, Hudson Bay Railway between Chesnaye and Cromarty, and Pikwitonei [Piquitenay], Manitoba (JBW) constitute a substantial eastern extension of the known range, and they differ biometrically from northwest *plicipennis*. The elytra are as long as or longer than wide, mean total length being 1.04 times the width; 13 individuals from Washington and Oregon have elytra wider than long, mean total width being 1.03 times length. However, one specimen from Washington has elytra slightly longer than wide. The male genitalia (Fig. 6) are similar in samples examined throughout the range of this species, but it is suggested that differences in elytral measurements from the localities mentioned may be of

some subspecific significance.

Most of the localities represented in available collections of this species are from Washington and Oregon (Fig. 9) west of the Cascade Range as follows: WASHINGTON: Ocean Park, Long Lake, Clear Lake, Pierce County; Evans Creek, King County; Naselle River near Naselle, Bothell, Bay Center, and Scribner Lake, Snokomish County (MHH); OREGON: Munsel Lake near Florence, Lane County, and Eugene (BM). Two individuals (Aklavik in Northwest Territories, on left bank near mouth of Mackenzie River) are similar to typical *plicipennis* from the Pacific Northwest.

GENERAL DISTRIBUTION OF *advenus* AND ALLIES

The records available show that *plicipennis* occurs in the Hudsonian, Oregonian, and Coloradan biotic provinces (Dice, 1943) from Rocky Mountain National Park, Colorado, slightly north of 40° N. lat., to Aklavik, Northwest Territories, approximately 100 miles north of the Arctic Circle. The greatest number of records for this species is from a narrow belt west of the Cascades in Washington and Oregon. Most of the records for *advenus* and *rossi* are within the Hudsonian and Canadian provinces, the exceptions being one record each for *rossi* in the northeast Illinoian and close to the northern border of the Carolinian. *Stenus advenus* occurs within the range of *rossi* and possibly the two are habitat sympatric, since both species are known to occur in two localities in Michigan and Quebec. So far as observed the three species inhabit marshland and probably are distributed much more widely than present records indicate.

SUMMARY

Three species of *Stenus* of the subgenus *Hypostenus* are treated taxonomically, with keys to the species represented by both sexes. *Stenus rossi* is described as a new species, from northern Illinois, Michigan, Vermont, and several Canadian provinces. *Stenus agnatus* Casey is synonymized with *plicipennis* Casey. The taxonomic value of the male genitalia and terminal abdominal segments for distinguishing these species is demonstrated. A map showing the present known distribution of *advenus* Casey and allies is presented.

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FOSSIL PROTOZOANS FROM THE KEEWATIN SEDIMENTS

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Introduction

Sedimentary rocks interbedded with igneous pre-Cambrian rocks occur in the Schreiber-Nipigon district of Ontario, Canada. In the Lower Gunflint cherts, Tyler and Barghoorn (1954) discovered "... five morphologically distinct organic entities." They stated that "... these are the oldest structurally preserved organisms that clearly exhibit cellular differentiation and original carbon complexes which have yet been discovered in pre-Cambrian sediments." Their estimated age is nearly two billion years. Older sediments of Keewatin age occur near the town of Schreiber as lenses of conglomerate, quartzite, limestone or chert interlayered with magnetite embedded in lavas. The entire formation dips from 55° to 70° N to NW (Harcourt, 1939).

Embedded in the fine-grained quartz of the black Keewatin cherts are the fossilized remains of at least 15 separate species of primitive organisms. The individual fossils which appear as detailed brown stains, often with coalified internal structures, include three bacteria, two blue-green, two green and one red algae, two euglenoids, four flagellates and one heliozoan. Magnetite-helium ratios (Hurley, 1949) and K_{40}/A_{40} (Goldich, *et al.*, 1956) date Algoman intrusives at 2.1 to 2.5 average 2.35 billion years. From this and from stratigraphic considerations, the estimated age of the Keewatin cherts appears to be from 2.6 to 2.8 billion years, with the higher value more probable.

This paper is concerned with the Keewatin protozoans, their morphology and possible systematic positions. In the Gunflint sediments, Tyler and Barghoorn (1954) found unicellular organisms which resemble *Discoaster*, a group of planktonic, calcareous marine flagellates of uncertain systematic position, probably related to the Coccolithophorides. No other information is available for protozoans of pre-Cambrian time.

Acknowledgment

This study was supported by a grant from the University Research Board, University of Illinois.

Materials and Methods

The Keewatin cherts were collected during the summers of 1955 and 1956 from a large chert-magnetite outcrop on King's Highway 17 about one mile west of Schreiber, Ontario. As no earlier evidence indicated the presence of fossils, samples were collected at random along the face of the outcrop.

In the laboratory the cherts were sawed with a diamond saw into sections about 2 mm. thick. From these, standard thin sections were prepared and mounted on microscope slides.

Results

Most of the thin sections of Keewatin chert showed coalified carbon structures with almost no internal detail. Some pieces of chert yielded thin sections with a different type of fossil material. These were brownish colored. Microscopic examination revealed that the dominant structures were probably the thallus and carposporangia of a red alga, most closely related to the modern Cryptonemiales. Between and on the fronds of the red alga were several bacterial and algal forms as well as protozoans. The bacteria and algae are being reported elsewhere.

The protozoans are represented by seven species, often fully as sharp and distinct as those seen in living protozoans; however, any conclusions must be tentative and subject to re-interpretation as more fossil material becomes available for study. Kudo (1954) and Hall (1953) were used in identifying these animals.

FAMILY EUGLENIDAE. — Genus *Euglena.* Two different species were found. The first (Fig. 1) is ovoid, 210 by 105 microns, slightly pointed at the anterior end, with a reservoir anteriorly. Within the reservoir is a dark granule, the blepharoplast; from it a long, slender filament, the flagellum, proceeds anteriorly out the cytostome and then posteriorly a short distance. The nucleus is round, dark, slightly anterior, and central. There are numerous fusiform chromatophores and round bodies with small coalified central granules.

The second species (Fig. 2) is an elongated cylinder with rounded ends, 210 by 67 microns. There is a large anterior reservoir with two peripheral granules, blepharoplasts (?). There is no evidence of a flagellum. The slightly posterior nucleus has two rounded bodies adjacent to it, paramylon bodies (?). Fusiform chromatophores are present as are numerous rounded bodies.

FAMILY OIKOMONADIDEA. — Genus *Oikomonas.* An ovoid form (Fig. 3), 46 by 28 microns, apparently uninucleate (the nucleus seems to be dividing). Anteriorly there is a small granule from which projects a short filament, the remains of a flagellum (?). Posteriorly, numerous granules outline several vacuoles. The cytoplasm is clear.

Genus *Ancyromonas.* Two distinct species were found. The first (Fig. 4) is small, triangular, and 8.5 by 8 microns. The remains of a flagellum from one of the apices may be present. Nucleus is vesicular, and there are several large vacuoles. This species most nearly resembles *A. contorta.*

The second form (Figs. 5 and 6) is larger, triangular, and 31 by 20 microns. There is evidence of a flagellum from the acute apex. The nucleus is uncertain. Numerous vacuoles were found, some with included coalified granules. This organism is not like any modern species known to the writer.

FAMILY AMPHIMONADIDAE.—Genus *Amphimonas.* A sub-spherical flagellate, 19 by 14 microns (Fig. 7). There is evidence of two flagella

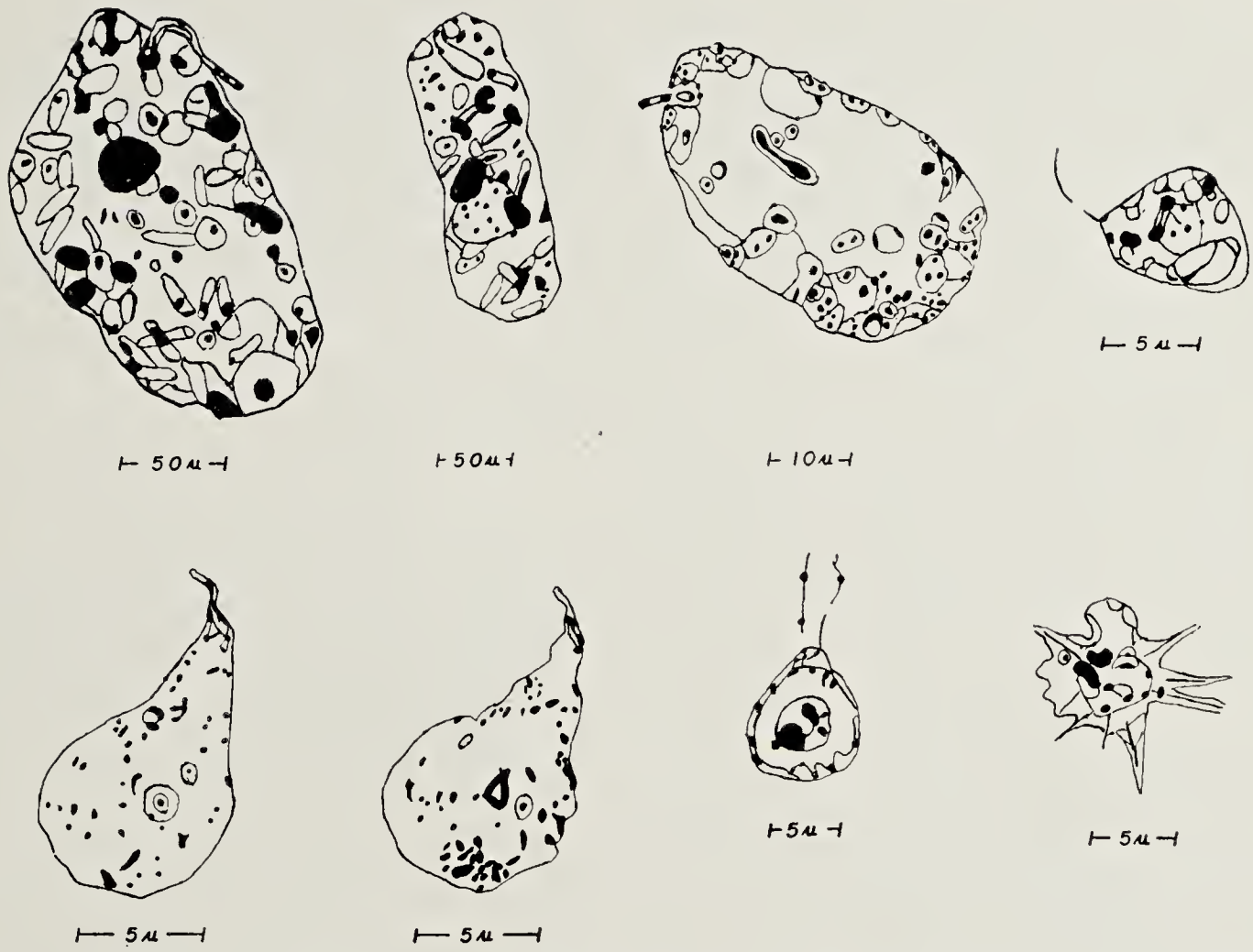

FIG. 1.—*Euglena* sp.; FIG. 2.—*Euglena* sp.; FIG. 3.—*Oikomonas* sp.; FIG. 4.—*Ancyromonas contorta* (?); FIG. 5.—*Ancyromonas* sp.; FIG. 6.—*Ancyromonas* sp.; FIG. 7.—*Amphimonas globosa* (?); FIG. 8.—*Sphaerastrum* sp. All thin sections.

projecting from the anterior end. The nucleus is large, central and coalified. The cytoplasm is dense. This form is similar to *A. globosa.*

FAMILY LITHOCOLLIDAE. — Genus *Sphaerastrum.* This heliozoan is small, 10 microns (Fig. 8). Numerous axopodia are covered with a gelatinous matrix. There is a central granule and a vesicular nucleus. This amoeboid species is smaller than the modern *S. fockei,* but resembles it.

DISCUSSION

The presence of seven species of protozoans representing the subclasses Phytomastigina, Zoomastigina and Actinopoda, and living between the thalli of a red alga during Keewatin time, estimated to be 2.6 to 2.8 billion years ago, is significant for three problems in theoretical biology. These are: 1) the stability of protozoan forms; 2) the diversity of the Keewatin protozoan fauna; and 3) the age of the earth's crust and the origin of life.

1. *Stability of protozoan forms.* In general, the genera of multicellular animals are geologically short-lived, infrequently surviving unchanged for more than a single period. The identification of protozoan genera from the Keewatin with modern ones indicates that, from the morphological point of view at least, these organisms are more enduring than any other known animals.

2. *Diversity of the Keewatin protozoan fauna.* The presence of seven

protozoans representing two classes and three sub-classes on the fronds of a red alga 2.6 to 2.8 billion years old indicates that the Keewatin fauna was rich in number of species, at least with regard to Mastigophora and Sarcodina. Further, it suggests that animals separated from plants at some earlier time.

3. *Age of earth's crust and origin of life.* Rankama (1954) placed the formation of the earth's crust at 3.35 billion years, and Sagen (1957) used 4.5 billion years. Subsequently, life originated and organisms evolved. Two theories are current on the origin of life, the heterotrophic theory of Haldane (1933) and the autotrophic one of Madison (1953). Both of these require a long slow series of events. The flora and fauna in these cherts is the first morphological evidence that these events occurred prior to Keewatin time.

Summary

The black Keewatin cherts from Schreiber, Ontario, dated at 2.6 to 2.8 billion years, contain the remains of 15 species of organisms belonging to the Schizomycetae, Cyanophyta, Chlorophyta, Rhodophyta, and Protozoa. These are the oldest morphologically preserved fossils that have been discovered to date.

The protozoans are represented by seven species belonging to five modern genera—namely, *Euglena, Oikomonas, Ancyromonas, Amphimonas,* and *Sphaerastrum.* Two of the species are similar to, if not identical with, living protozoans.

The significance of this discovery is discussed with regard to the stability of protozoan forms, the diversity of the Keewatin protozoan fauna, and the age of the earth's crust and the origin of life.

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NEW SPECIES OF EIMERIA (PROTOZOA: EIMERIIDAE) FROM MEXICAN RODENTS

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Materials and Methods

During the summer of 1956 the University of Illinois Natural History Museum and Graduate College sponsored a collecting expedition to Mexico. The three mammalogists who were members of the expedition, William Z. Lidicker, Jr., Wayne H. Davis and John R. Winkelmann, collected fecal samples from 23 rodents of various species, placed them in 2.5% potassium bichromate solution, and brought them back to Urbana for examination. Each sample was mixed thoroughly, placed in a thin layer in a Petri dish for a week to sporulate, and stored in a refrigerator. The samples were examined microscopically after sugar flotation, using a Leitz Ortholux microscope with apochromatic objectives.

The present paper describes five new species of *Eimeria* and redescribes *E. callospermophili* Henry, 1932, from a new host.

The skins and skulls of the host animals are preserved in the University of Illinois Natural History Museum. The numbers given with the host designations below are those of the host animals in the museum.

We should like to express our appreciation to Messrs. Lidicker, Davis, and Winkelmann and to Dr. Donald F. Hoffmeister, director of the museum, for collecting the specimens and identifying the hosts.

Results

Eimeria callospermophili Henry, 1932

Description: Oocysts (Figs. 1, 2) spherical to subspherical. Oocyst wall colorless to pale yellowish, slightly rough and pitted, composed of single layer about 1.1 microns thick. Micropyle absent. Fifty-three sporulated oocysts measured 15 to 27 by 14 to 25 microns, with mean of 20.1 by 19.0; length-width ratios ranged from 1.0 to 1.1, with mean of 1.06. Sporulated oocysts contained four lemon-shaped sporocysts measuring about nine by seven microns; Stieda body present. Oocyst refractile granule present. Oocyst residuum composed of several large, homogeneous bodies. Sporocyst residuum absent or composed of one to 15 or more round granules. Sporozoites often at ends of sporocysts, but may lie lengthwise in them.

Some oocysts were seen (Fig. 2) which contained only two sporocysts, each with two sporozoites, and thus resembled *Cyclospora*. However, they resembled *E. callospermophili* in all other characteristics. In addition, abnormal oocysts of other types were present; these included oocysts with three normal sporocysts, with two normal and one giant sporocysts, or with one, two, three or four imperfectly developed sporocysts. It was concluded that the *Cyclospora*-like forms were actually abnormal *E. callospermophili*.

Host: Citellus spilosoma spilosoma (U. Ill. Mus. No. 12,468) (spotted ground squirrel).

Location: Intestinal contents.

Locality: Host trapped by Mr. Winkelmann on July 7, 1956, seven miles north of Rincon de Romos, Aguascalientes, Mexico.

Remarks: Of the ten species of *Eimeria* which have been described from ground squirrels of the genus *Citellus,* the present form most closely resembles *E. callospermophili* Henry, 1932, which was described from *C. lateralis* (syn., *Callospermophilus chrysodeirus*) in California. However, while the oocyst wall of the present form is composed of a single layer, that of *E. callospermophili* was said to be "probably" composed of two layers, although they could not be separated.

Henry (1932) stated that the oocysts of *E. callospermophili* were subspherical and gave their dimensions as 16.0 to 22.4 by 16.0 to 22.4 microns, with a mean of 19.2 by 16.0. There is obviously an error in the figures for width, but whether it is the range or the mean which is wrong cannot be determined. The sporocysts of *E. callospermophili* measure 10.2 by 8.5 microns, while those of our form are 9 by 7. Furthermore, Henry's description makes no mention of the Stieda body or the position of the sporozoites in the sporocysts, and these cannot be determined from her photomicrographs. However, in the absence of a more detailed description of *E. callospermophili* from the original host species, these differences do not appear to warrant the creation of a new species for the form from *C. spilosoma.*

Eimeria hoffmeisteri new species

Description: Oocysts (Fig. 4) subspherical. Oocyst wall colorless to pale yellowish, smooth, composed of single layer about 1.0 micron thick. Micropyle absent. Seven sporulated oocysts measured 15 to 20 by 13 to 18 microns, with mean of 17.7 by 16.1 microns; length-width ratios ranged from 1.0 to 1.2 with mean of 1.10. Sporulated oocysts contain 4 elongate ovoid sporocysts about 11.5 by 6.0 microns; Stieda body absent or inconspicuous. Oocyst refractile granule present. Oocyst residuum absent or composed of few homogeneous bodies. Sporocyst residuum composed of large amount of finely granular material. Sporozoites either at the ends of the sporocysts or lying somewhat longitudinally.

Host: Citellus spilosoma spilosoma (U. Ill. Mus. No. 12,468) (spotted ground squirrel)

Location: Intestinal contents.

Locality: Host trapped by Mr. Winkelmann on July 7, 1956, seven miles north of Rincon de Romos, Aguascalientes, Mexico. *E. callospermophili* was found in same animal.

Remarks: Ten species of *Eimeria* have been described from ground squirrels of the genus *Citellus. E. citelli* Kartchner and Becker, 1930, was described from *C. tridecemlineatus* in Iowa and has since been reported from *C. pygmaeus* in the U.S.S.R. and from *C. citellus* in Hungary (see Pellérdy and Babos (1953) for references). *E. beecheyi* Henry, 1932, was described from *C. beecheyi* in California. *E. bilamellata* Henry, 1932, was described from *C. lateralis* in California and has since been reported from *C. citellus* in Hungary by Pellérdy and Babos (1953). *E. callospermophili* Henry, 1932, was described from *C. lateralis* in California and is reported from *C. spilosoma* from Mexi-

co in the present paper. *E. volgensis* Sassuchin and Rauschenbach, 1932, was described from *C. pygmaeus* in the U.S.S.R. *E. beckeri* Yakimoff and Sokoloff, 1935, was described from *C. pygmaeus* in the U.S.S.R. *E. franklinii* Hall and Knipling, 1935, and *E. eubeckeri* Hall and Knipling, 1935, were described from *C. franklinii* in Iowa. *E. ussuriensis* Yakimoff and Sprinholtz-Schmidt, 1939, was described from *C. (Spermophilus) eversmanni* in Siberia. *E. lateralis* Levine, Ivens and Kruidenier, 1957, was described from *C. lateralis* in Arizona.

E. hoffmeisteri differs from *E. lateralis, E. bilamellata, E. callospermophili,* and *E. eubeckeri* in having a smooth rather than a rough oocyst wall. It differs from *E. bilamellata, E. eubeckeri,* and *E. volgensis* in lacking a micropyle. It differs from *E. beckeri, E. beecheyi, E. bilamellata, E. citelli, E. eubeckeri,* and *E. ussuriensis* in having an oocyst refractile granule. It differs from *E. franklinii, E. lateralis, E. citelli,* and *E. eubeckeri* in not having a prominent Stieda body. It differs from *E. beecheyi* in having a sporocyst residuum. It most closely resembles *E. franklinii,* but differs from it in being subspherical rather than elongate as well as in the Stieda body character.

Eimeria dipodomysis new species

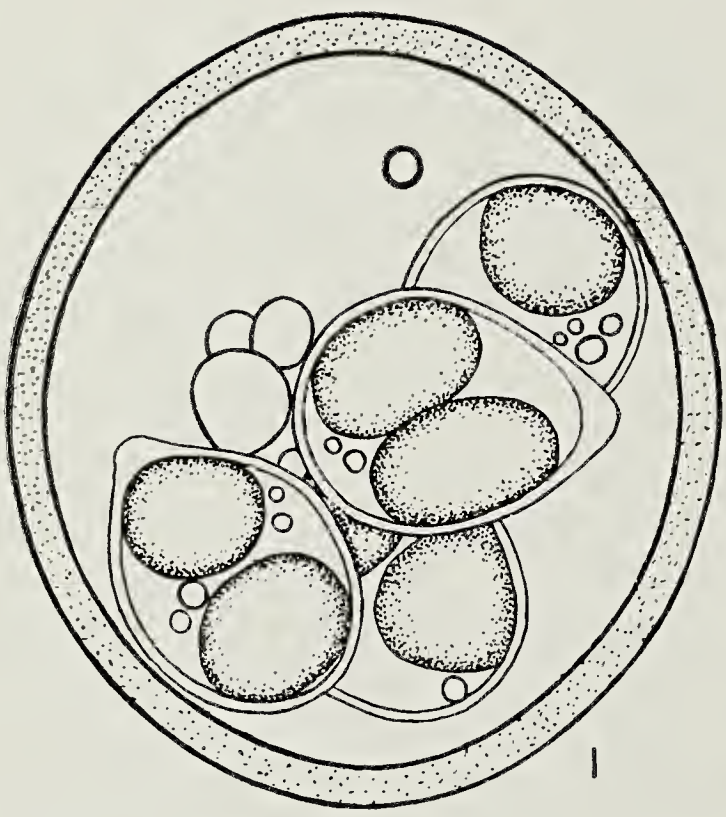
Description: Oocysts (Fig. 7) ellipsoidal. Oocyst wall yellowish brown, rough, of two layers—outer one 3.5 microns thick at sides and 3.0 at ends, and inner one 0.7 microns thick. Micropyle absent. Seventeen sporulated oocysts measured 47 to 61 by 38 to 42 microns, with mean of 54.1 by 40.2 microns; length-width ratios ranged from 1.2 to 1.5, with mean of 1.35. Sporulated oocysts contained 4 ovoid sporocysts measuring about 16 by 11 microns. Stieda body shaped like a somewhat conical dome, *i.e.*, excavated in the center. No oocyst refractile granule could be distinguished. Oocyst residuum large, composed of a mass of homogeneous granules. In some oocysts these granules were few, large and loosely aggregated, while in others they were small and numerous, forming a compact mass. Sporozoites embedded in a large amount of sporocyst residual material.

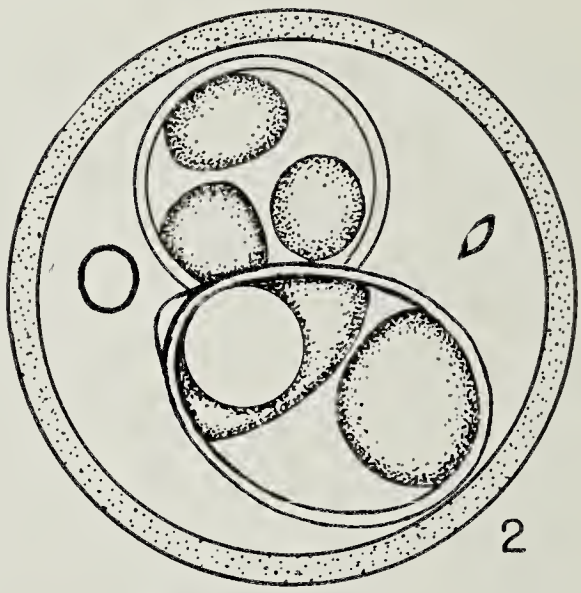
Host: *Dipodomys ornatus* (U. Ill. Mus. No. 12,369) (ornate kangaroo rat.)

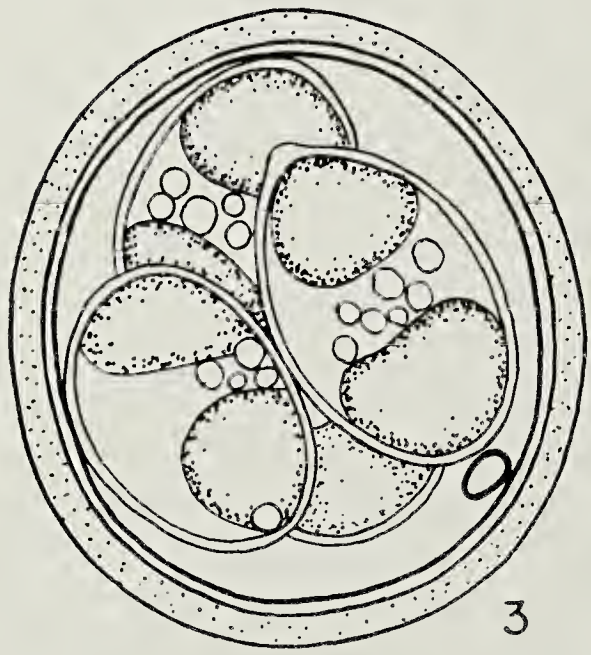
Location: Intestinal contents.

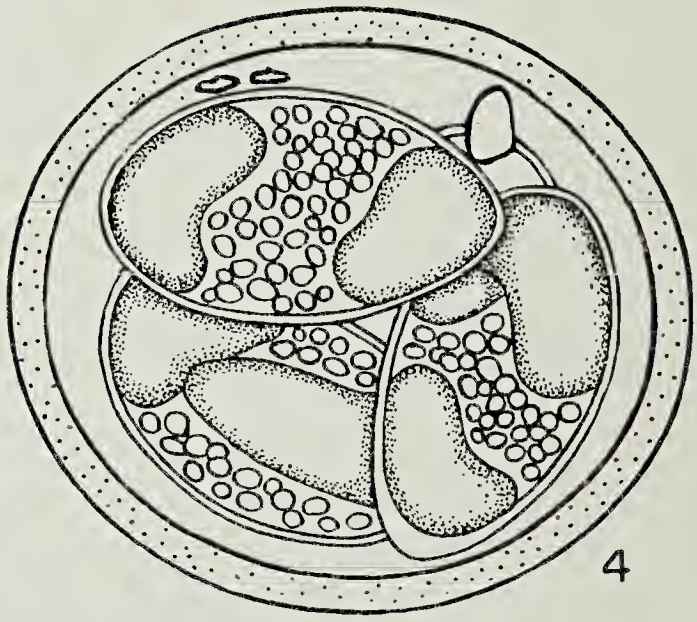
Locality: Host trapped by Mr. Winkelmann on July 6, 1956, 16 miles south of Aguascalientes, Aguascalientes, Mexico. Another *D. ornatus* from the same locality and a third from Lagos de Morenos, Jalisco, were negative.

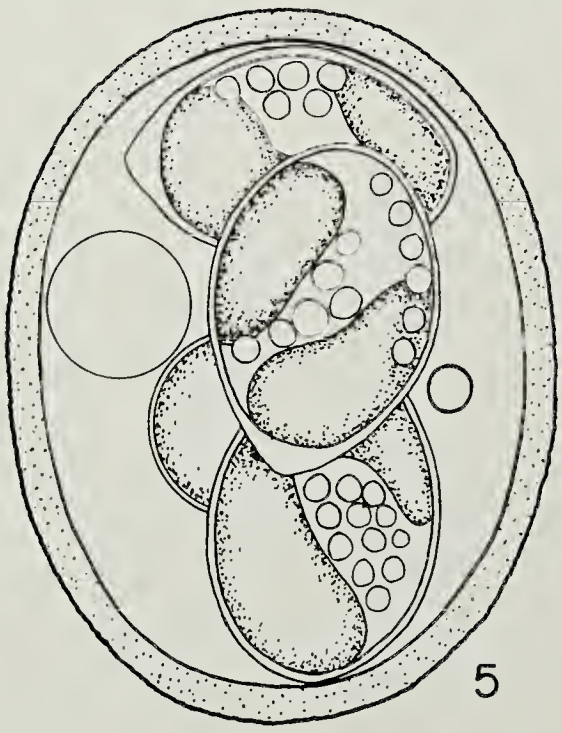
Remarks: Four other species of *Eimeria* have been described from rodents of the family Heteromyidae. *E. mohavensis* Doran and Jahn, 1949, was described from *Dipodomys panamintinus* in California by Doran and Jahn (1952), and *E. perognathi* Levine, Ivens and Kruidenier, 1957, was described from *Perognathus intermedius* in Arizona. *E. liomysis* and *E. picti* are described below from *Liomys pictus* and *L. irroratus. E. dipodomysis* averages more than twice as long or wide as any of these and has a much heavier, rougher, darker wall. The only rodent *Eimeria* which resemble it at all are *E. botelhoi* Carini, 1932, from the squirrel, *Sciurus (Guerlinguetus) ingrami,* in Brazil, *E. petauristae* Ray and Singh, 1950, from the Himalayan flying squirrel, *Petaurista inornatus,* in India, and *E. mira* Pellérdy, 1954, from the common squirrel, *Sciurus vulgaris,* in Europe. However, all of these have a micropyle and only











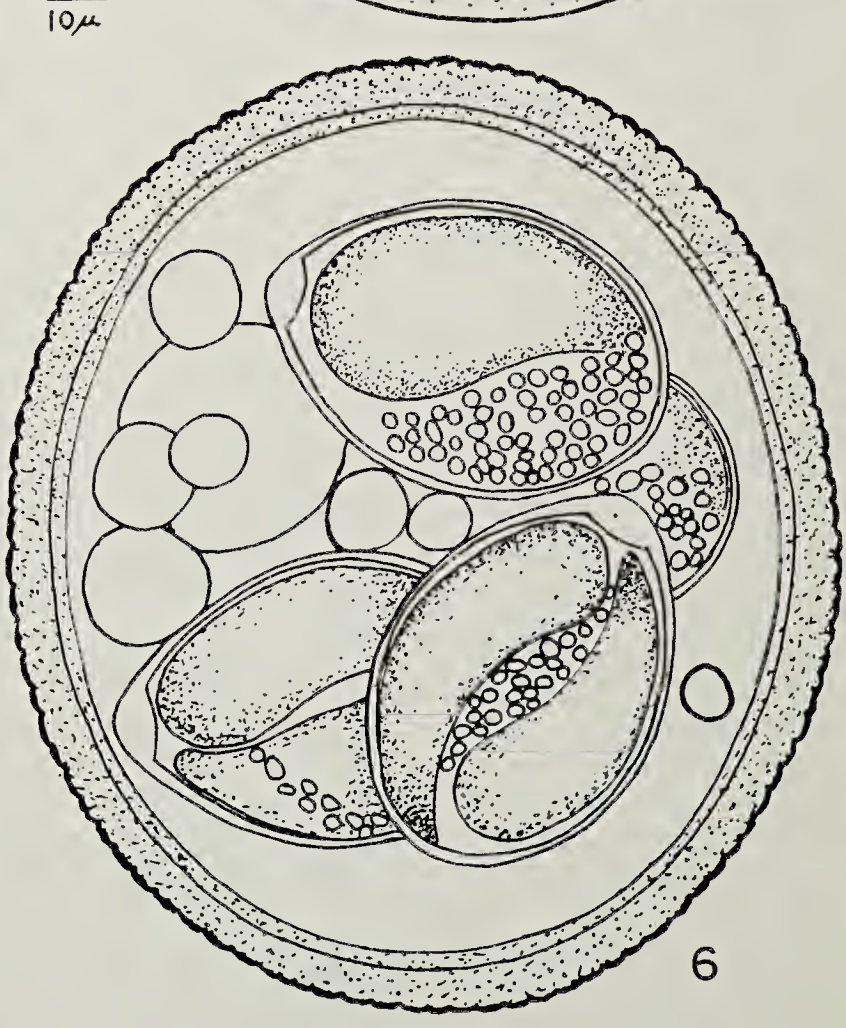


Fig. 1.—*Eimeria callospermophili* Henry, 1932, from *Citellus s. spilosoma*, x 2600. Fig. 2.—Abnormal *E. callospermophili* containing two sporocysts; from *C. s. spilosoma*, x 2600. Fig. 3.—*Eimeria liomysis* n. sp. from *Liomys pictus*, x 2600. Fig. 4.—*Eimeria hoffmeisteri* n. sp. from *Citellus s. spilosoma*, x 2600. Fig. 5.—*Eimeria baiomysis* n. sp. from *Baiomys taylori*, x 2600. Fig. 6.—*Eimeria picti* n. sp. from *Liomys pictus*, x 1400.

E. petauristae approaches *E. dipodomysis* in size.

Eimeria liomysis new species

Description: Oocysts (Fig. 3) subspherical to ellipsoidal. Oocyst wall of two layers—outer one 0.9 microns thick, pale yellow, slightly rough and pitted, and inner one 0.3 microns thick and practically colorless. Micropyle absent. Seventy-five sporulated oocysts from two specimens of the type host measured 15 to 24 by 14 to 21 microns, with mean of 19.5 by 17.7; length-width ratios ranged from 1.0 to 1.3, with mean of 1.10. Forty-four sporulated oocysts from a *Liomys irroratus* measured 15 to 23 by 14 to 20 microns, with mean of 18.2 by 17.2; length-width ratios ranged from 1.0 to 1.1, with mean of 1.06. Sporulated oocysts contained 4 almost ellipsoidal to ovoid sporocysts about 10 by 7 microns, with small Stieda body. Oocyst refractile granule present. Oocyst residuum absent. Sporozoites usually at the ends of the sporocysts, with some relatively large residual granules between them.

Type Host: Liomys pictus (U. Ill. Mus. Nos. 12,690 and 12,692) (painted spiny pocket mouse).

Other Host: Liomys irroratus (U. Ill. Mus. No. 12,713) (Mexican spiny pocket mouse).

Location: Intestinal contents.

Locality: L. pictus trapped by Mr. W. Z. Lidicker, Jr., on July 26, 1956, 11 miles northeast (by road) of Copala, Sinaloa, Mexico. *L. irroratus* trapped by Mr. Lidicker on July 14, 1956, 11 miles southeast (by road) of Guadalajara, Jalisco, Mexico.

Remarks: Four other species of *Eimeria* had been described from rodents of the family Heteromyidae (see remarks under *E. dipodomysis* above). *E. liomysis* differs from *E. mohavensis, E. perognathi and E. dipodomysis* in being more nearly spherical and in having an oocyst refractile granule. It differs from *E. mohavensis* in having a small

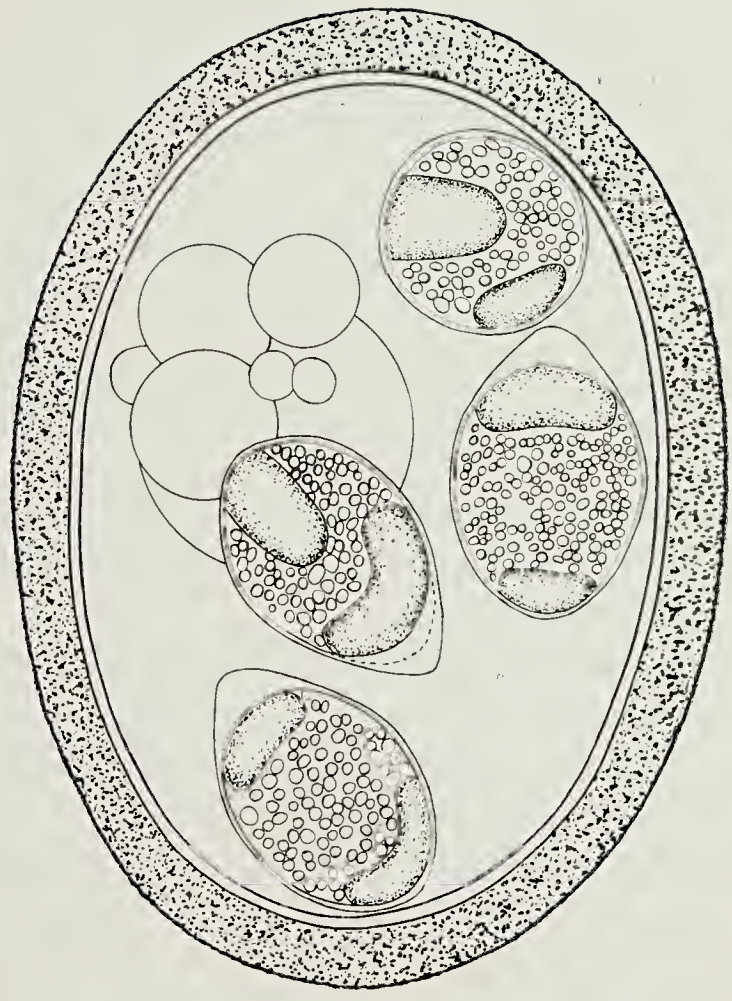


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FIG. 7.—*Eimeria dipodomysis* n. sp. from *Dipodomys ornatus*, x 2600.

Stieda body and from *E. perognathi* in lacking an oocyst residuum and in having much larger sporocysts. It is much smaller than *E. dipodomysis* and differs further from it in lacking an oocyst residuum and in having smaller sporocysts and a less noticeable Stieda body. It differs from *E. picti* in being smaller and in lacking an oocyst residuum.

Eimeria picti new species

Description: Oocysts (Fig. 6) subspherical to ellipsoidal. Oocyst wall of two layers—outer one brownish yellow, 1.3 microns thick, rough and pitted, and inner one brownish yellow and 0.4 microns thick. When outer wall is broken, inner wall usually remains intact. Micropyle absent. Fifty-three sporulated oocysts measured 22 to 32 by 19 to 28 microns, with mean of 25.8 by 22.5:

length-width ratios ranged from 1.0 to 1.2, with mean of 1.15. Sporulated oocysts contained 4 broadly lemon-shaped sporocysts measuring 11 to 12 by 8 to 9 microns; Stieda body present. One or two oocyst refractile granules present. Oocyst residuum usually composed of a number of large, clear irregular granules, but sometimes was a single large, granular mass. Sporocyst residual material composed of a few to many granules. Sporozoites lie longitudinally, head to tail, in the sporocyst.

Host: *Liomys pictus* (U. Ill. Mus. No. 12,692) (painted spiny pocket mouse).

Location: Intestinal contents.

Locality: Host trapped by Mr. W. Z. Lidicker, Jr., on July 26, 1956, 11 miles northeast (by road) of Copala, Sinaloa, Mexico. The same animal was infected with *E. liomysis*.

Remarks: Four other species of *Eimeria* have so far been described from rodents of the family Heteromyidae (see remarks under *E. dipodomysis* above). *E. picti* differs from all but *E. liomysis* in having an oocyst refractile granule. It is much smaller than *E. dipodomysis* and has a much thinner wall. It differs from *E. mohavensis* in having an oocyst residuum and sporocyst Stieda body. It differs from *E. perognathi* in shape and in having a two-layered oocyst wall. It is larger than *E. liomysis* and differs further from it in having an oocyst residuum.

Eimeria baiomysis new species

Description: Oocysts (Fig. 5) ellipsoidal. Oocyst wall yellowish, quite rough and pitted, of single layer 1.6 microns thick. Micropyle absent. Twenty-five sporulated oocysts measured 20 to 25 by 18 to 21 microns, with mean of 22.9 by 19.3; length-width ratios ranged from 1.0 to 1.3 with mean of 1.19. Sporulated oocysts contained 4 ovoid sporocysts about 11.0 to 11.5 by 7 to 8 microns; Stieda body present. Oocyst refractile granule present. Oocyst residuum a homogeneous body. Sporocyst residual material composed of coarse granules. Sporozoites lie lengthwise in sporocysts.

Host: *Baiomys taylori* (U. Ill. Mus. No. 13,026) (pigmy mouse).

Location: Intestinal contents.

Locality: Host trapped by Mr. W. Z. Lidicker, Jr., on July 5, 1956, eight miles east of Queretero, Queretero, Mexico. Two other *B. taylori* collected in the same locality were uninfected.

Remarks: Eleven species of *Eimeria* have been described from rodents of the subfamily Cricetinae. One of these, *E. criceti* Pellérdy, 1956, was described briefly by Nőller (1920) from the wild European hamster, *Cricetus cricetus* (tribe Cricetini), under the name *E. falciformis* var. *criceti*. *E. baiomysis* is much larger and also differs from it in having an oocyst residuum.

The other ten species were described from rodents of the tribe Hesperomyini to which *Baiomys* belongs. They are: *E. neotomae* Henry, 1932, from *Neotoma fuscipes* in California; *E. residua* Henry, 1932, from *N. fuscipes* in California; *E. oryzomysi* Carini, 1937, from *Oryzomys* sp. in Brazil; *E. phyllotis* Gonzales-Mugaburu, 1942, from *Phyllotis amicus* in Peru; *E. operculata* Levine, Ivens and Kruidenier, 1957, from *Neotoma stephensi* in Arizona; *E. albigulae* Levine, Ivens and Kruidenier, 1957, from *N. albigula* in Arizona; *E. onychomysis* Levine, Ivens and Kruidenier, 1957, from *Onychomys leucogaster* in Arizona; *E. peromysci* Levine, Ivens and Kruidenier, 1957, and *E. arizonensis* Levine, Ivens and Kruidenier,

1957, from *Peromyscus truei* in Arizona; and *E. eremici* Levine, Ivens and Kruidenier, 1957, from *P. eremicus* in Arizona.

E. baiomysis differs from *E. oryzomysi, E. phyllotis,* and *E. operculata* in having an oocyst refractile granule. It differs from *E. neotomae, E. phyllotis,* and *E. operculata* in having an oocyst residuum. It differs from *E. operculata* in having a sporocyst residuum and in not having an oocyst operculum. It differs from *E. neotomae, E. oryzomysis, E. operculata, E. arizonensis,* and *E. eremici* in having a rough, pitted wall. Its wall differs from that of *E. albigulae* in being composed of a single layer rather than of two, of which the outer layer is colorless and the inner one pale brownish. In addition, its sporozoites lie lengthwise in the sporocysts, while those of *E. albigulae* are polar. It differs from *E. onychomysis* in having an oocyst wall three times as thick. It is much smaller than *E. peromysci* and also differs from it in having an oocyst wall composed of a single layer rather than of two and in having much smaller sporocysts. It differs from *E. residua* in having a yellowish wall composed of a single layer rather than a brown one composed of two layers and in being more elongate. This latter difference is emphasized by a comparison of Henry's photomicrograph of *E. residua* with our own photomicrographs of *E. baiomysis.* In addition, the oocysts of *E. baiomysis* are somewhat smaller and the sporocysts somewhat larger than those of *E. residua.* These species resemble each other quite closely, but the relatively small differences enumerated above combined with the difference in host genus justify the establishment of a new species for the form from *Baiomys.*

Summary

In a survey of 23 rodents of 12 species from Mexico, the following species of *Eimeria* were found and described: *E. callospermophili* Henry, 1932, and *E. hoffmeisteri* n. sp. from the spotted ground squirrel, *Citellus s. spilosoma; E. dipodomysis* n. sp. from the ornate kangaroo rat, *Dipodomys ornatus; E. liomysis* n. sp. from the painted spiny pocket mouse, *Liomys pictus,* and the Mexican spiny pocket mouse, *L. irroratus; E. picti* n. sp. from *L. pictus;* and *E. baiomysis* n. sp. from the pigmy mouse, *Baiomys taylori.* This raises to 34 the number of species of North American rodents from which *Eimeria* has been described, and to 55 the number of species of *Eimeria* occurring in them.

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OBSERVATIONS AND NEW RECORDS OF HYMENOPTERAN PARASITES OF LYCAENID EGGS (LEPIDOPTERA)

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Two species of parasites were recovered from eggs of *Plebejus* (*Icaricia*) *icarioides* (Bdv.), a polymorphic polytypic butterfly occurring in western North America. *Trichogramma minutum* Riley (Trichogrammatidae) was recovered from eggs of the host butterfly collected in Utah, Nevada, and California, and *Telenomus* sp. (Scelionidae) was reared from eggs of a Utah population.

T. minutum is of widespread occurrence throughout the United States and Canada, and it is known to parasitize more than 100 species of butterflies. Other than *Plebejus icarioides* reported here, only one species in the subfamily Plebejinae (*Hemiargus hanno* Stroll) has been recorded as a host (Muesebeck *et. al.*, 1951). *T. minutum* was reared from eggs of *P. icarioides* collected in the following localities (the number after each locality is the number of eggs collected; the percentage of eggs parasitized is in parentheses): Parley's Canyon, Salt Lake Co., Utah, 14 (57); Austin, Lander Co., Nevada, 12 (33); Lamoille, Elko Co., Nevada, 7 (57); Pequop Summit, Elko Co., Nevada, 118 (52); Rutherford, Napa Co., California, 36 (69); and Fawn Lodge, Trinity Co., California, 28 (28).

Telenomus sp. emerged from 13 of 45 eggs of *P. icarioides* (Bdv.) collected at 5200 feet elevation in Big Cottonwood Canyon, Salt Lake County, Utah. The parasite is probably an undescribed species. A nearby locality, Parley's Canyon, Salt Lake County, Utah, 6,000 feet elevation. had a higher percentage of parasitized eggs (57%), but all the parasites were *Trichogramma minutum* Riley which was not found in the former population. Only one other species of the genus *Telenonomus* has been recorded as a parasite in the family Lycaenidae (*T. grapta* Howard, parasite of *Lycaena phlaeas hypophlaeas* (Bdv.)).

Although the infra-specific taxonomy of the polymorphic host remains to be settled, the Great Basin populations of the butterfly mentioned above have been considered as belonging to the subspecies *P. i. ardea* (Edw.), while the California populations could be assigned to *P. i. icarioides* (Bdv.).

Newcomer (1911) has described the complete life cycle of *P. icarioides* (Bdv.) under the name *Lycaena fulla* Edw. He reported that a considerable number of field-taken larvae had tachinid eggs on them, and he also obtained a braconid parasite from a larva which had hibernated. As far as known to me, Newcomer's records and those mentioned above are the only records of parasites of this butterfly.

The host has a somewhat localized, semi-clustered distribution of populations throughout western North America, following the spotty distribution of the lupine plants on which the larvae feed. This distribu-

tion is somewhat misleading in terms of commonness and rareness of the butterfly. Local concentrations of the lupines and the unequal distribution of eggs on the plants undoubtedly give rise to local concentrations of egg parasites. However, the non-specificity of *T. minutum* would suggest that the heavy parasitism of some of the populations may be the result of an unusual increase in numbers of the parasite on hosts other than *P. icarioides*. The early spring emergence of the host populations in most areas and the shorter peroid of time available for oviposition in populations from more stringent ecological areas (desert and Great Basin populations) lend weight to this belief. However, the percentage of eggs parasitized seems to be greater later in the year.

An unsuccessful attempt was made to correlate site of oviposition with parasitism in populations from which large numbers of eggs were collected. There were as many parasitized eggs found on the upper surfaces of the leaves as were taken on the lower surface, the petioles, and the stems. Percentage of parasite emergence from eggs laid at these sites was also comparable.

Several cases of "superparasitism" (Salt, 1936) were observed in which more than one parasite occurred in one egg. In two eggs thus superparasitized (one from Fawn Lodge, California, and one from Pequop Summit, Nevada) the chalcids failed to emerge. However, eight adult parasites were recovered from four eggs collected at Lamoille, Nevada, and many egg shells of other hosts populations were noted which had more than one emergence hole.

The size and color of the individuals of *T. minutum* varied considerably in the samples observed from the three-state area. As an aftermath of such studies as Salt (1941) on the affects of hosts on parasites, there has been even more emphasis placed on the population aspects of host-parasite relationship, and a followup study on this morphologically variable parasite on a morphologically variable host seems desirable.

The fact that as many as 69% of the eggs of a population of *P. icarioides* can be destroyed by *T. minutum* implies that egg parasitism may be a significant factor in population density in some areas. If it does affect density, the reproductive rate of these isolated populations will be lowered considerably and, through random selection, parasitism may account for part of the intra-population variation observed in the host.

I am grateful to Dr. R. L. Doutt of the University of California for identification of the parasites. Representatives of all of the parasite populations discussed have been deposited in the collection at the University of California, Gill Tract Insectary, Albany, California.

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COLLEGIATE

A PARASITE OF THE SWIM BLADDER OF BLACK CATFISH

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Introduction

During the summer of 1956, a study of the parasitic fauna of fishes in the Fox River, 18 miles north of Aurora, was undertaken. Initially, the emphasis was placed on the overall group of the Platyhelminthes and their general relationship to these fishes. However, because of the apparently high trematode population in certain fishes, this class of parasites became the focal point of the project.

The authors wish to thank Dr. S. H. McFarlane of Aurora College for his ever present encouragement and interest in the project. Also, we express our gratitude to Dr. Lyell Thomas of Urbana for his aid.

Methods

The fishes used for study were obtained from shallow, muddy waters by seining and were examined shortly after being caught. Of the 40 fishes examined, 3 were small *Lepomis numilis,* 8 were *Cyprinus carpio* (3 to 4 inches in length) and 29 were *Ameiurus melas* of varying sizes.

Results

The *Ameiurus* received our entire attention when it was determined that 83% of the fish examined harbored a small trematode, *Acetodextra amiuri* (Stafford, 1900; Pearse, 1924). Invariably, the worm was loosely attached to the inside of the swim bladder. None of the other kinds of fishes investigated was found to be host to such an organism. This is probably due to the difference in the accessibility of the swim bladder in the three types of fishes. Further, the parasite was not detected in any other organ of the catfish. This is not entirely consistent with the findings of other investigators, for Stafford (1900) discovered the worm in the liver of the catfish and Pearse (1924) located an encysted *Acetodextra* in the liver peritoneum of a *Schilbeodes gyrinus.*

No correlation could be made between the size of the fish and the number of parasites in the swim bladder, since all but two of the catfish examined were under five inches in length. It was noted, however, that a two-inch length was the lower limit in the size of the infected host. The number of worms present in the swim bladder varied from one to nine.

Discussion

When a search of the literature concerning *Acetodextra aminuri* was undertaken, it was felt that specimens from the Fox River were vari-

ants of the species. This was concluded because the descriptions by Stafford (1900) and Pearse (1924) were somewhat incomplete and did not entirely agree with our findings. The parasites from the Fox River were much smaller than those of Pearse's account. Secondly, Pearse reported the ovary of the worm to be lobate and elongate. In contrast, the parasites considered in this study were noted as having a definite and consistently lobated, circular ovary. Upon further investigation, it was found that Van Cleave and Mueller (1931 and 1932), had made a more complete study of *Acetodextra amiuri* and that their accounts were more compatible with our observations. Therefore, the concept of a variant was discarded.

It is felt, however, that the results of this study are significant in two ways. First, the 83% infestation in the Fox River catfish was a great deal higher than the 15% recorded by Van Cleave and Mueller (1934). However, these investigators did not state the sizes of the fish examined and this factor may have some bearing on the difference in results.

The second pertinent facet of this study lies in the fact that this is the first known recording of *Acetodextra amiuri* in Illinois catfishes.

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A MORE EFFICIENT MOLD FOR PLASTIC EMBEDDING

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Introduction

As the technique for plastic embedding becomes more and more familiar to biology departments everywhere, the need for improving and modifying its inefficiencies becomes more and more apparent. One such inefficiency is the time-consuming and expensive method by which a plastic block is usually finished. The sides and edges of the block must be trimmed to remove the rounded corners left by the mold; the mold has such a shape (instead of squared edges) for easier removal of the plastic block. The surface layer of the block must be sanded down sometimes three-sixteenths of an inch; the surface layer of the block always remains tacky and unhardened because of its contact with the air. These two steps involve time, expensive tools, and a large loss of costly plastic. Although the sanding and buffing which follow these steps are unavoidable, the rounded edges and tacky surface layer may be eliminated by using a collapsible mold-form with a drying agent such as calcium chloride.

Collapsible Mold-Form

The mold-form which is pictured in Figures 1 and 2 is a wooden box of two parts. The two wooden sides have a tongue-and-groove arrange-

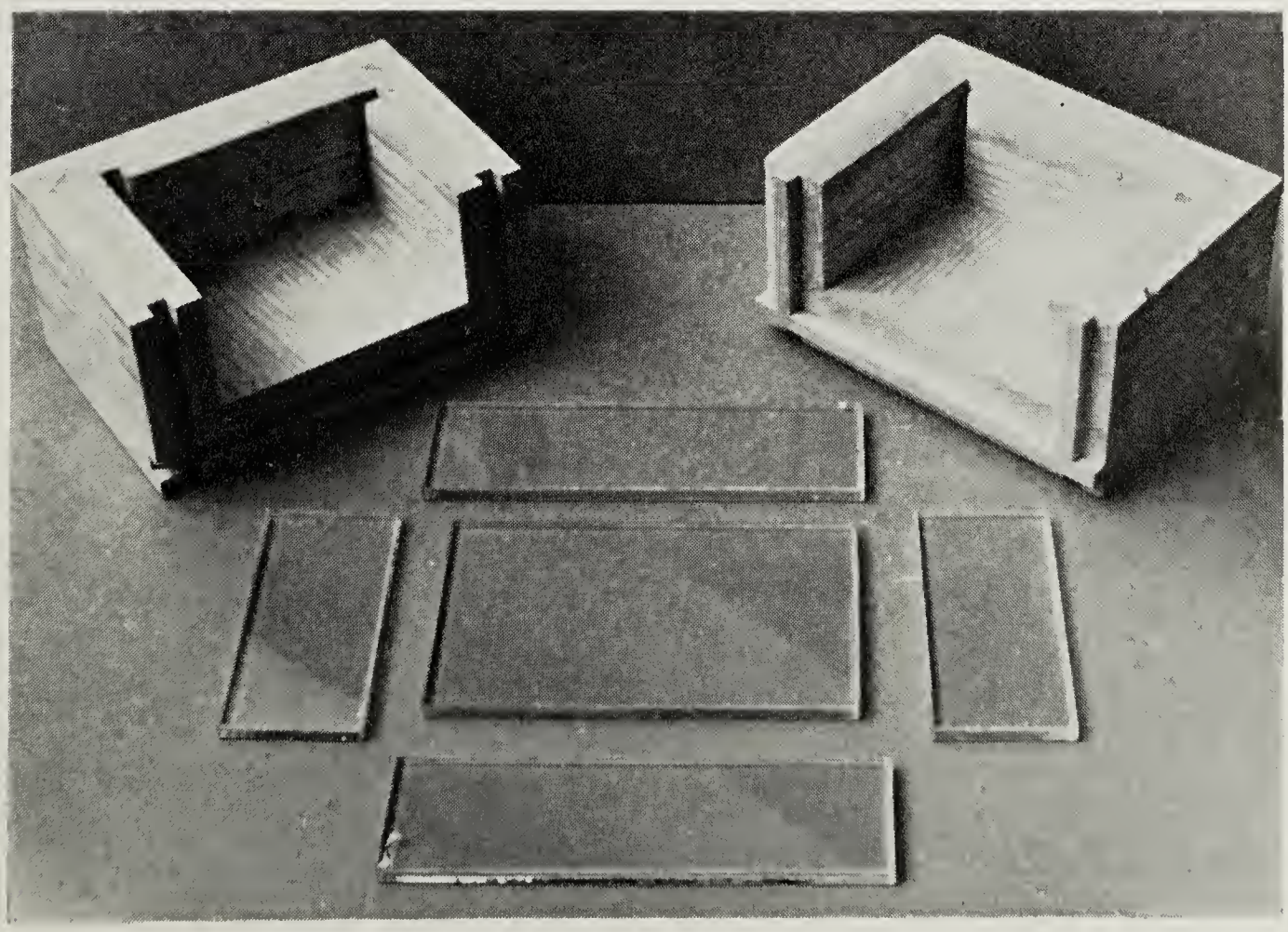

Fig. 1.—Collapsible mold-form taken apart.

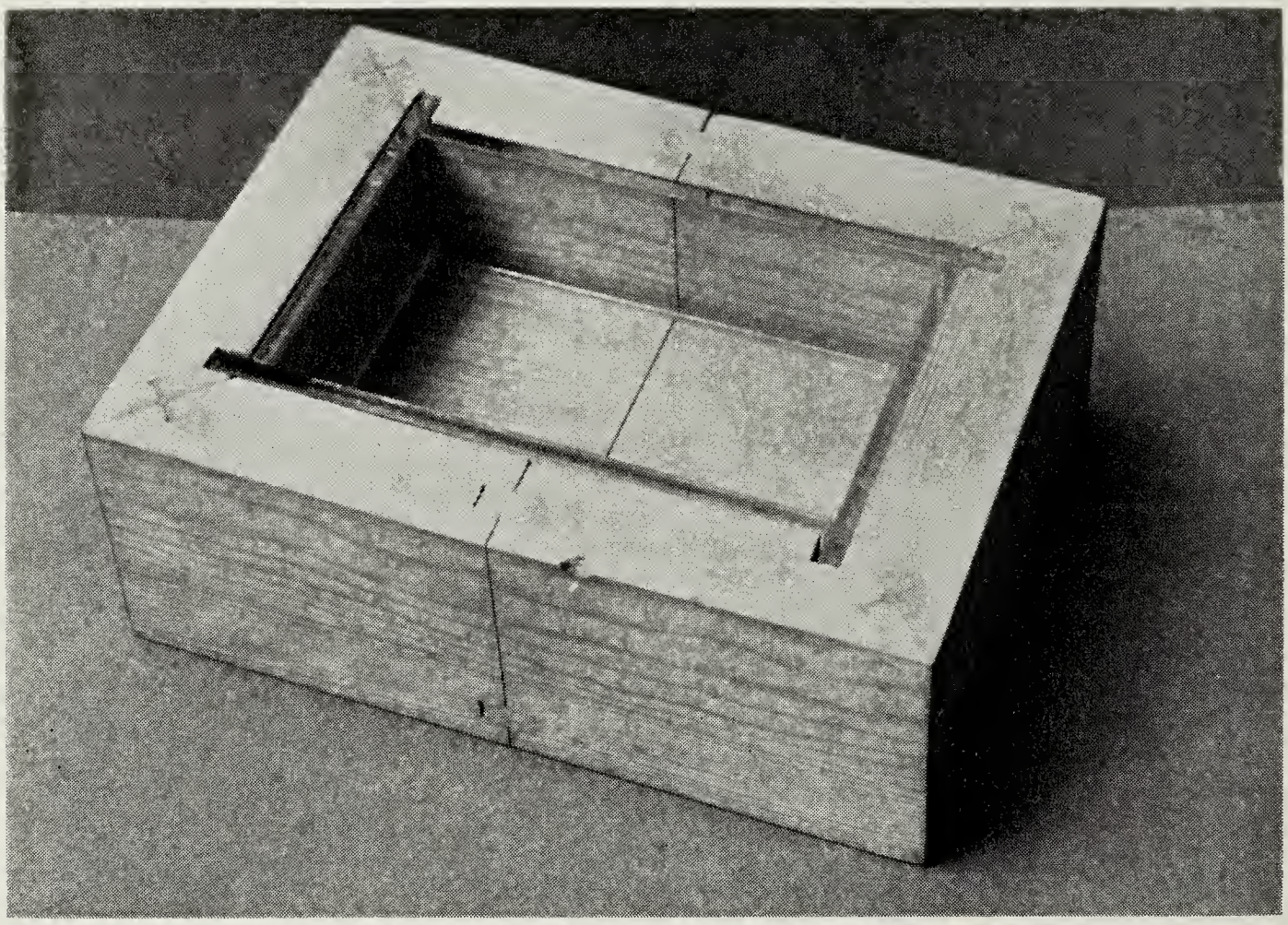

FIG. 2.—Collapsible mold-form completed.

ment for tighter joining and, inside, the bottom and four sides are all separate pieces of glass. Figure 2 shows the completed form with its squared inside corners that make trimming or cutting unnecessary. Its internal dimensions allow for a plastic block 5″ by 3″ with a thickness up to 1.5″. Because of the tight joints and thick walls, the form is resistant to the usual 60° C. temperature of the curing oven and may be used indefinitely. Finally, the removal of the plastic block is simplified, just pull apart the two sides.

The depth of the tacky surface layer may be reduced considerably by sealing off the plastic from the moisture-laden air in the following way. To the underside of a piece of plate glass fix a small cap containing a drying agent such as calcium chloride. The glass is then sealed to the top of the mold-form with vaseline, leaving a chamber over the surface of the plastic. During the curing process, the vaseline melts, and the expanding, moisture-laden air escapes. Later, upon cooling, a partial vacuum is formed in the chamber forcing the glass downward. At the same time, the vaseline solidifies and keeps new moisture out of the chamber and moisture already present is absorbed by the drying agent. Tackiness is reduced to a point where only normal sanding and buffing are necessary.

If both the collapsible mold-form and the drying apparatus are used, there is an elimination of the usual sawing and excessive sanding involved in finishing a plastic block. The reduction in the overall amount of plastic used results in a saving of time and cost, and, finally, the plastic block may be finished without the aid of expensive machinery.

ELECTROLYSIS of AQUEOUS ∂-CYCLOHEXYLBUTYRATE

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In the Kolbe electrolysis, an organic anion dissolved in a polar solvent (usually water) yields an electron to an anode to become a free radical. The free radical decomposes, finally forming stable compounds. If the acid is RCOOH, the ion is RCOO, and the prime free radical is RCOO. The prime free radical usually largely decomposes, to CO_2 and the secondary free radical R. The dimer RR and the unsaturated compound (R minus H) are usually prominent products.

Certain structures within R inhibit the Kolbe action in water, so that hydroxide discharges instead of the organic anion. When this happens, oxygen replaces carbon dioxide in the anode gases. Thiessen (1950) recognized ethylenic and benzenoid inhibitions. Fichter and Holbro (1937) found that separation of the inhibiting ethenoid structure from the carboxylate end of the ion by two methylene groups cancelled the ethenoid inhibition. Fichter and Siegrist (1932) electrolyzed the cyclohexylcarboxylate ion in aqueous solution; their small yields showed the reality of a cyclohexanoid inhibition.

∂-cyclohexylbutyric acid has recently become commercially available. In it, three methylenes separate the inhibiting cyclohexyl group from the carboxylate unit. This separation might be expected to mitigate the inhibition. We, therefore, electrolyzed concentrated aqueous solutions of the potassium salt of this acid to find if it would yield more Kolbe products than its first homologue.

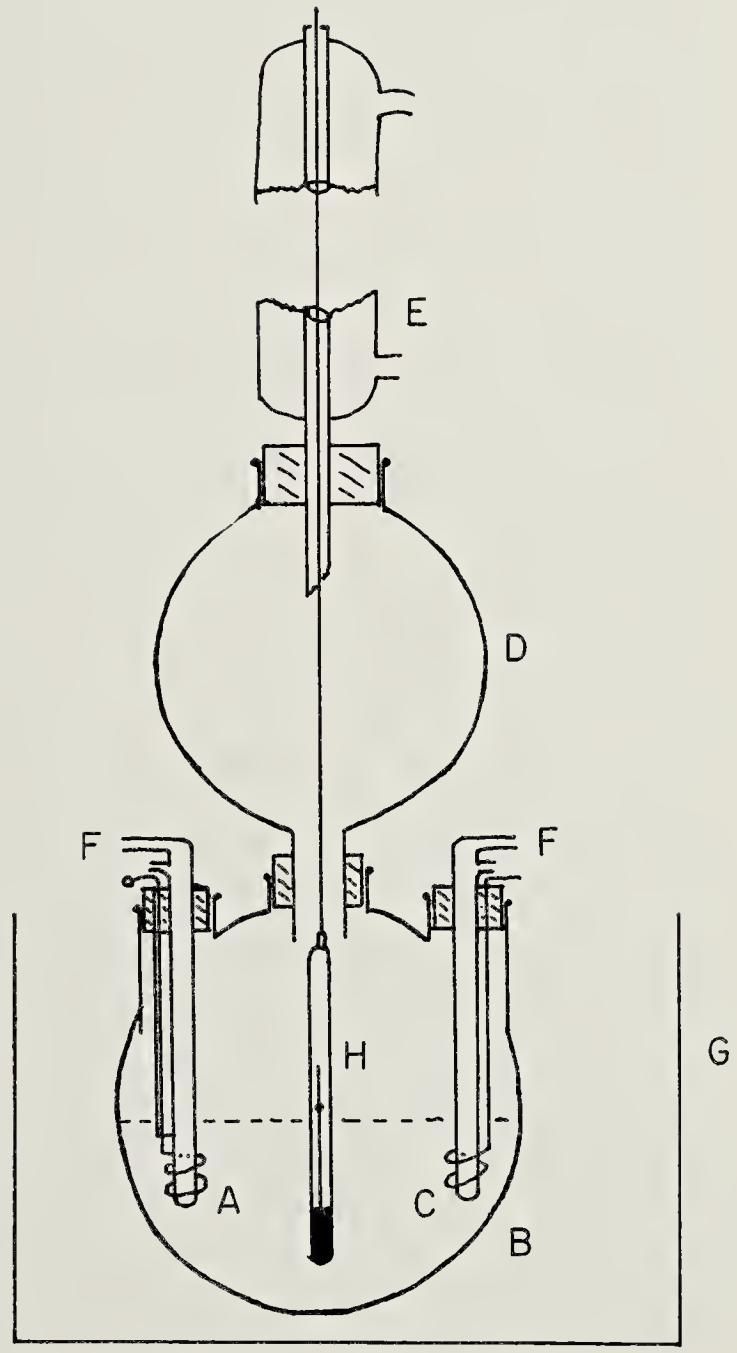

FIG. 1.—Electrolysis cell with accessories: *A*, anode (Pt wire with glass sheath); *B*, three-neck flask, 250 ml.; *C*, cathode (Pt wire); *D*, foam chamber; *E*, reflux condenser; *F*, cold-finger condensers; and *G*, tank for external cooling.

TABLE 1.—Conditions and Results

Run	1	2	3	4	5
conc. salt	1.40 M.	1.40 M.	1.77 M.	1.77 M.	1.77 M.
vol. used	100 ml.	200 ml.	100 ml.	100 ml.	100 ml.
anode current density (*amp* cm^2)	1.33	1.33	4.17	4.17	4.17
time (hrs.)	37	27.5	16.6	18.4	25.5
faradays	2.21	1.64	3.10	3.43	4.75
temp. cell, °C	63-68	63-68	63-68	60	46
external temp., °C	20	20	20	0	0
CO_2 evolved	yes	none[1]	yes	yes	not measurable
yield, R-H, gms.	app. 4	none	app. 4	app. 5	none
yield, of RR	none	none	trace	trace	none
gas stirring	no	no	no	no	yes[2] with N_2 and air

[1] No CO_2 was evolved, and two phases did not appear within 27.5 hours; therefore, the run was discontinued. Runs (3, 4 and 5) were made under different conditions.

[2] Lippincott (1954) reported that Kolbe electrolysis favored production of saturated hydrocarbons below 50° C. Stirring was used to lower temperature to 43° C. However, Kolbe reaction did not take place and most of original acid was recovered.

EXPERIMENTAL

The apparatus is shown in Figure 1. The large intermediate chamber *D* was used to eliminate difficulties due to foaming. Electrodes were of platinum. Internal and external cooling was employed. A motor generator furnished direct current. Experimental conditions and results are summarized in Table 1.

The Eastman acid was used without further purification and converted to the salt solution by treatment with a concentrated solution of potassium hydroxide and water. After electrolysis, yields were recovered from the reaction mixtures by ether extraction and dried with magnesium sulfate. The dicyclohexane was collected by vacuum distillation and purified by washing with cold, concentrated sulfuric acid. Material passing over at lower temperature was collected separately and is supposed by us to be (R minus H).

Even in the most favorable runs, the amount of RR isolated was so small that the refractive index was the only numerical identifying constant which could be taken. Our value ($n_D^{23} = 1.480$) was in good agreement with the values ($n_D^{20} = 1.4765$) of Schlenk (1951 and ($n_D^{21} = 1.4758$) of Fieser and Leffler (1948).

The presumed (R minus H) came also in small amounts, though it was more abundant than the RR. It dissolved completely in 80% aqueous sulfuric acid solution, which indicates it is either unsaturated or oxygenated. It decolorized dilute permanganate solution, which actions indicate unsaturation. Its density was 0.855 gm./cc. at 25° C.; n_D^{25} was 1.468, and its boiling point approximated 110° at 14 mm. pressure. These constants agree fairly well with the Beilstein values of (a) 3-cyclohexyl propene-1 (d_4^{19} = 0.813, n_D^{19} = 1.449, b.p. = 152° at 760 mm.), (b) 1-propylcyclohexene (d_4^{19} = 0.8216, n_D^{19} = 1.455, b.p. = 158° at 760 mm.), and 3-propylcyclohexene (d_4^{19} = 0.8181, n_D^{19} = 1.454, b.p. = 155° at 760 mm.). The agreement is, however, not good enough to distinguish the location of the double bond.

R. Best and G. W. Thiessen of Monmouth College found, in unpublished research, that an improved yield of RR resulted from the electrolysis of the potassium salt of δ-cyclohexylbutyric acid in a pyridine-methanol solution, under the conditions of Fichter and Petrovitch (1940).

Conclusion

The low yields of typical Kolbe products in the electrolysis of aqueous δ-cyclohexylbutyrate ion, comparable to those of Fichter and Siegrist (1932), show that cyclohexanoid inhibition of the Kolbe electrolysis cannot be cancelled by even three methylenes intervening between the carboxylate and inhibiting groups. This contrasts with ethenoid inhibition, which can be relieved by two methylenes thus intervening.

Acknowledgments

The above study was directed by G. W. Thiessen, working under a National Science Foundation grant. Paul Ray did important preliminary experiments.

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ACADEMY BUSINESS

SECRETARY'S REPORT OF THE BUSINESS OF THE ILLINOIS STATE ACADEMY OF SCIENCE FOR THE YEAR MAY 5, 1956, TO MAY 4, 1957

Compiled by

ROBERT A. EVERS, *Secretary*

The 50th annual meetings of the Illinois State Academy of Science were held at Normal, Illinois, on May 3 and 4, 1957, with the Illinois State Normal University as host. The programs of the 10 sections included 106 papers and the total attendance at the section meetings was 455.

The general session of Friday morning, May 3, held in Capen Auditorium, opened with a Welcome by Dr. Robert G. Bone, President, Illinois State Normal University. The welcome was followed by the Presidential Address of Miss Joan Hunter. Miss Hunter's address was entitled "Let the Chips Fall Where They May."

At 10:45 a.m., Dr. John Bardeen, Professor of Electrical Engineering and Physics, University of Illinois, spoke on "Semi Conductor Research Leading to the Point Contact Transistor." This interesting lecture was sponsored jointly by the Academy of Science and the Bloomington-Normal Chapter of Sigma Xi.

The Junior Academy program showed continued growth. There were 910 exhibits in McCormick Gymnasium, and 605 persons attended the Junior Academy banquet. The Senior Academy members set aside the 11:30 a.m. time on the Friday program for visiting the Junior Academy exhibits.

The Academy luncheon was informal and was held in the Student Union Cafeteria.

The annual banquet was held in the cafeteria of the Normal Community High School. As has been the custom for a number of years at the annual banquet, the past presidents of the Academy were asked to rise.

The evening meeting was held in the auditorium of the Normal Community High School. The program was opened

by Dr. G. R. Yohe, Chairman of the Science Talent Search Committee, with the presentations of the winners of the Annual Science Talent Search. Dr. Yohe reported that 160 high-school teachers requested 1,192 examination papers for the 16th Annual Westinghouse Talent Search. Of these, 192 were completed and submitted to the Science Clubs of America for judging. Illinois students won 5 of the 40 Washington trips and 19 of the 260 National Honorable Mentions. The Science Talent Search Committee of the Academy selected 14 additional State Honorable Mention awards from the remaining 168 entries.

Dr. N. R. Brewer, Illinois Society for Medical Research, presented the awards for the essay contest sponsored jointly by that Society and the Academy.

The annual public lecture was the premier showing of the film "Illinois Indians of the Stone Age", narrated by Milton D. Thompson, Assistant Director, Illinois State Museum.

Council Meetings

The Council held four meetings during the year. The first meeting was held in the Anniversary Room of the St. Nicholas Hotel, Springfield, Illinois, on May 5, 1956.

Miss Elnore Stoldt reported that 129 clubs registered for the Junior Academy program, that 710 exhibits were presented in the Springfield Armory, and that 830 persons attended the Junior Academy banquet. Dr. Gross discussed the enlargement of the Yearbook, a project which the Council approved and voted $200.00 additional funds to cover the cost.

The Council voted to add $57.50 to the amount received from the A.A.A.S. for research grants to cover most of the requests. Dr. Grimm pointed out that this sum can come from interest on the investments in the permanent fund.

The Council appointed Mr. C. W. Hudelson, Illinois State Normal University, to the office of Second Vice-President and set the dates for the 50th annual meeting in Normal, Illinois, as May 2, 3, and 4, 1957. The Council also appointed Harvey I. Fisher as Technical Editor for the next year, James S. Ayars as Publicity Adviser, and Francis Kruidenier and R. A. Evers as members of the Publication Committee.

President Joan Hunter presented a proposal from A.A.A.S. concerning research grants. After a discussion of this matter, Dr. Shanor was directed to prepare a letter for A.A.A.S., recommending that: 1) our present plan of distribution be continued; 2) state academies be permitted autonomy in this matter, in view of the different situations that are likely to prevail in the several states; 3) a summarized report of the Research Grants Committee be included; and 4) that copies be sent to other state academies.

Dr. Neckers submitted the proposed budget for 1956-57 which was approved in a modified form.

Mr. Thompson presented the problem of inaccuracies and errors in facts in some educational films used in schools. He suggested that the Academy give some thought to the improvement of these films. By Council approval, President Hunter appointed Mr. Thompson Chairman of a committee to study these films.

The second meeting of the Council was held in the Green Room of the St. Nicholas Hotel, Springfield, Illinois, on November 10, 1956.

President Hunter reported that Dr. Robert Bone had accepted the invitation to give the welcoming address at Normal. She also read a letter from a Citizens Committee in Education (a subdivision of the former White House Committee) in which the Academy was asked to appoint a member to that committee. The Council appointed Dr. E. L. Stover.

The Secretary announced that by mail vote the Council had unanimously elected Dr. Paul Shaffer as Councilor and Dr. H. J. Fuller as Collegiate Section Coordinator to fill vacancies caused by the resignations of Dr. Leland Shanor and Dr. F. H. T. Rhodes.

Dr. Deuel, Librarian, informed the Council that Volume 44 of the *Transactions* was out of print. In the ensuing discussion concerning the *Transactions*, the Council agreed that exchange publications should go to scientific institutions free of charge. The Council also agreed that it be the general policy of the Academy that each member receive one copy of the *Transactions* and that additional copies may be obtained, if available, upon payment of the proper fee ($2.00) until a change becomes necessary.

The Council granted a request from the Illinois Society for Medical Research that the Academy allow that organization ten minutes of the evening program of the annual meeting of the Academy in order to grant the awards of the

Essay Contest. The Council also approved the appointment of a committee to investigate the possibility of reestablishing the Medical Section of the Academy and to investigate the possibility of setting up a series of one-day health workshops in various cities in Illinois. Dr. Floyd Boys was appointed chairman of this committee.

Upon the request of Dr. G. R. Yohe, Chairman of Science Talent Search Committee, the Council appointed Dr. Paul Silva and Dr. Ralph Yeatter to fill vacancies which occurred in this committee.

Dr. G. R. Theissen announced to the Council that the National Science Foundation granted the Academy $7,000.00 for assistance in holding an Undergraduate Research Conference in February, 1957. Dr. Theissen was appointed Director of the Conference. Dr. Welch, Treasurer, was instructed to set up the proper accounts to administer this grant.

The third meeting of the Council was held in the Green Room of the St. Nicholas Hotel, Springfield, Illinois, on February 16, 1957. Dr. Gross reported briefly on the activities of the Junior Academy and the Junior Academy Conference.

Mr. Neil Hardy reported on the Steering Committee of the Illinois Curriculum Program. After a discussion, the Council instructed the Secretary to write the Superintendent of Public Instruction asking that a member of the Senior and Junior Academy have membership on this Committee.

President Joan Hunter told the Council that she had agreed to act as a judge of the Essay Contest of the Illinois Society for Medical Research. She had attended the Junior Academy Conference, and she had been informed that the Illinois Association of School Boards had been studying the problem of arousing the interests of students in science.

The Secretary reported that a change in location and registered agent of the Academy, a non-profit organization, was necessary according to Corporations Laws of the State of Illinois. The Council approved the Secretary's action on changing the location of the office of the Academy to 393 Natural Resources Building, Urbana, Illinois, and they approved Robert A. Evers as the registered agent.

Mr. C. W. Hudelson, Second Vice-President, told about preparations for the annual meeting at Normal, Illinois, in May. The Council approved the times set for general meetings, banquets, and luncheons, and also discussed other details of the annual meeting.

Dr. Kanatzar gave the report of the Sustaining Membership Committee including the announcement of a gift from Mr. Goethe for memberships for postgradute Students. The Council instructed Mr. Boewe, Chairman of the Membership Committee, to extend active membership to such students who meet the requirements of Mr. Goethe's request and are duly recommended for membership.

The Secretary summarized the report of the Committee on Medical Section and Health Workshop. The Council accepted the report of Dr. Floyd Boys, Chairman of the committee. and ordered the report filed. The Council also discharged the committee and tabled further action on the report.

Dr. Ekblaw presented a draft of the revised constitution which was discussed and amended. The revised draft was mailed to all members of the Academy.

The Council approved the speakers for the annual meeting—Dr. John Bardeen, University of Illinois, for the morning session, and Mr. Milton Thompson, Illinois State Museum, for the evening session.

The fourth meeting of the Council was held on Thursday, May 2, 1957, in the Private Dining Room, Student Union Building, Illinois State Normal University, Normal, Illinois, with Miss Joan Hunter presiding. Mr. C. W. Hudelson reported on local arrangements. The officers, committee chairmen, and section chairmen made preliminary reports. They presented the final reports at the annual business meeting on Friday, May 3, 1957. These reports are included below.

Annual Business Meeting

The business meeting of the 50th annual meetings of the Illinois State Academy of Science was held May 4, 1957, in Capen Auditorium, Illinois State Normal University, Normal, Illinois, at 5:00 p.m. C.D.T., with President Joan Hunter presiding.

The report of the Secretary, which follows, was seconded by Dr. W. B. Welch and accepted.

The minutes of the business meeting of the 49th annual meetings, held in the Green Room, Hotel St. Nicholas, Springfield, Illinois, have been published in volume 49 of the *Transactions of the Illinois State Academy of Science.* They include the actions of the Council and

the reports of the standing and special committees, and the Treasurer.

Activities of the Academy have been summarized in the President's Annual Letter which, with the program of the annual meeting and the proposed constitutional revision, was mailed to each member.

Madame President, I move the acceptance of the report of the 49th annual meetings as published in volume 49 of the *Transactions* and also the summary of the year's activities as included in the President's Annual Letter.

Dr. Welch presented the Treasurer's report which follows. He moved acceptance of the report, Dr. Ekblaw seconded, and the motion carried.

Mr. James S. Ayars, Publicity Advisor, reported on the excellent cooperation he had with the Publicity Department of Illinois State Normal University in getting suitable publicity for the Academy meetings.

Reports of Standing Committees

Affiliations.— Dr. Ekblaw reported that a review of affiliations is being made but the review is not yet complete.

Budget.—Dr. J. W. Neckers submitted the report which is to be acted upon by the new Council. Dr. Necker's report is in the Secretary's files.

Membership.—Mr. G. H. Boewe summarized the activities of the Membership Committee. Mr. Boewe moved that persons who have applied for membership during the past year and who have met the qualifications be elected to membership. Dr. Welch seconded and the motion carried.

Sustaining Memberships.—Dr. C. Leplie Kanatzar reported that the Illinois State Academy of Science now has 62 Sustaining Members.

Reports of Special Committees

The report of the Auditing Committee was given by Dr. C. L. Foote who moved acceptance of the report which follows. Dr. Grimm seconded the motion which carried.

To whom it may concern:

This is to certify that the Auditing Committee has examined the financial accounts of the Treasurer of the Illinois State Academy of Science and has found them to be correct and to check with the statement of balance by the Carbondale National Bank. This audit was made as of May 1, 1957.

(signed) Charles L. Foote, *Chairman*
W. D. Klimstra
Irvin M. Peithman

Resolutions.—Dr. Paul Shaffer presented the report of the committee and the seven following resolutions were adopted by the Academy.

1. *Whereas*, the facilities provided and the arrangements and provisions for these 50th annual meetings of Illinois State Normal University have contributed to the success of this meeting,

   Be it resolved, that the Academy express its gratitude to the University through its President, Dr. Robert G. Bone, and to Mr. Clyde Hudelson, Second Vice-President, who was in charge of local planning, to Mrs. Gertude M. Hall, Director of Publicity, to Mr. Lincoln Murray Miller for audio-visual aids, and to Mr. Jackson and Mr. Schmidt of the Biology Department for their aid in many special arrangements, and
   Be it further resolved, that the Secretary be instructed to send a copy of this resolution to those named in it.
2. *Whereas*, Mr. E. L. Alexander and Mr. N. E. Correll, Superintendent and Principal, respectively, of Edwardsville High School have contributed to the work of the Academy by aiding its President in many ways during the past year,
   Be it resolved, that the Academy express its gratitude for this aid and the Secretary be instructed to send a copy of this resolution to the men named in it.
3. *Whereas*, bog areas in Illinois are gradually disappearing through reclamation activities.
   Be it resolved that the Illinois State Academy of Science support efforts currently being made by the Nature Conservancy to assure the preservation of Volo Bog in Lake County, Illinois,
4. *Whereas*, educational aspects of natural resource conservation are important and a sound conservation philosophy can be developed in students of the elementary and secondary school levels, and

   Whereas, such a philosophy can best be imparted to students by teachers who have an understanding of the basic principles of conservation and the ability to utilize local resources to impart these principles to their students, and

   Whereas, there is a definite need for more work in conservation at the

TREASURER'S REPORT

1956-57

BALANCE, May 1, 1956		$ 2,319.99
RECEIPTS		
Annual dues	$ 3,058.08	
Regular	$ 3,058.08	
Sustaining	1,940.00	
Life	150.00	
Registrations (Springfield)	172.60	
Refunds	6.50	
Interest		
U. S. bonds	75.10	
Savings	105.00	
Research grants	382.50	
Void checks	17.62	
National Science Foundation	$ 5,907.40	$ 8,227.39
Undergraduate Research Conference	$ 7,000.00	
TOTAL—balance and receipts		$ 15,227.39
EXPENDITURES		
Council	254.81	
Secretary's office	505.07	
Treasurer's office	271.46	
Editor's office	157.35	
Miscellaneous	45.98	
Research grants	440.00	
Membership committee	384.14	
Librarian's office	336.29	
Honoraria	740.00	
Junior Academy		
General	1,726.32	
Science talent search	474.64	
Sustaining membership committee	52.71	
	$ 5,388.77	
National Science Foundation, Undergraduate research conference	$ 2,917.81	
TOTAL expenditures		8,306.58
CASH ON HAND, April 30, 1957		6,920.81
Outstanding checks		568.78
ON DEPOSIT, Carbondale National Bank, April 30, 1957		$ 7,489.59
BALANCE, National Science Foundation		$ 4,082.19
INVESTED FUNDS		
Current		
State Savings & Loan Association, East St. Louis	$ 4,000.00	
Other reserved funds in bonds	1,800.00	
PERMANENT FUND		$ 5,800.00
Life memberships in—		
U. S. bonds	$ 1,200.00	
Cash in Carbondale Natl. Bank	450.00	
		$ 1,650.00
TOTAL, invested and permanent funds		$ 7,450.00

undergraduate level of the teacher training program,

Be it resolved that the Illinois State Academy of Science, through the teacher training committee and the conservation committee, actively promote such policies and curriculum requirements in the accrediting of elementary and secondary teachers as might be necessary to adequately train potential teachers of the Illinois school systems in conservation.

5. *Whereas* the conservation officers of the Illinois Department of Conservation have wide contacts with the public and thus may make a major contribution in establishing the foundation for an understanding of the conservation and management of our natural resources, and

   Whereas, present personnel in the law enforcement division are usually not professionally trained to meet adequately the needs of the citizens of this state,

   Be it resolved that the Illinois Academy of Science, through whatever means necessary, actively promote within the principles of the Academy a policy which would require that all personnel of the law enforcement division of the Illinois Department of Conservation be professionally trained and hold civil service status and receive salaries commensurate with their academic degrees, and

   Be it further resolved, that, in view of the present status of employed personnel, the attainment of professional status be instigated as follows:

   1. A compulsory two-week training school for all currently employed conservation officers be conducted annually on an academic campus with professional instructors representing the fields of fish, game, law, and public relations who will emphasize the fundamental principles of management, law enforcement, and conservation education with examinations terminating the program;
   2. All new and future employees be required to hold a Bachelor's Degree which included appropriate training in all phases of conservation and management of natural resources, law, public speaking, and public relations; and
   3. At such time as most conservation officers hold a Bachelor's Degree, the compulsory annual training program be limited to one week and serve the purpose of dissemination of and interpretation of new laws, management principles, and departmental policies.

6. *Whereas*, the Illinois Game and Fish codes and Forestry laws are in need of revision not only to clarify present regulations but also to serve more firmly and clearly as an adequate written document regarding the preservation and management of the fauna and flora of the State of Illinois, and

   Whereas the State of Illinois through its Department of Conservation should have the responsibilty for various biota which are not under present codes included within its jurisdiction and the responsibility for clarification of the present handbook of the codes so that all regulations are clearly and simply stated for the understanding of all persons affected,

   Be it resolved that the Illinois State Academy of Science actively promote within the principles of the Academy the revisions deemed necessary by the trained conservation leaders within the state to protect adequately the heritage so richly provided in our great State of Illinois.

7. *Whereas*, several members of the Academy have died during the past year,

   Be it resolved, that the Academy, by rising for a moment of silence, express its sympathy to the families of the deceased members listed below.

   Beimfohr, Oliver W., October, 1956
   Carlson, Anton J., September 2, 1956
   Engel, Charles C., October 5, 1956
   Hoskins, J. Hobart, February 8, 1957
   Kraybill, Henry R., September 30, 1956
   Louttit, C. M., May 24, 1956
   Poling, T. C., September 12, 1956

Reed, Frank H.,
April 27, 1957
Simkins, Cleveland S.,
October 14, 1956
Snow, Lucille H.
Walton, Howard Jr.,
1956

Constitutional Revision.—Dr. Ekblaw presented the report of this committee and moved that the revised constitution as drafted and corrected be adopted. Miss Dorothy Gore seconded the motion which carried. The revised constitution is published in Volume 50 of the *Transactions.*

Nominating.— This committee consisted of Dr. G. E. Ekblaw, *Chairman,* Dr. Harold R. Wanless, Dr. R. Maurice Myers, Dr. Wilbur W. Grimm, Dr. E. L. Hill, and Dr. James W. Neckers. Dr. Ekblaw presented a slate of officers for 1957-1958 and a roster of committee chairmen and committee members. This list will be published in the program for the 51st annual meetings and also in the *Transactions.* President Hunter called for further nominations from the floor. Dr. L. J. Thomas moved that nominations be closed. Dr. E. L. Stover seconded and the motion carried. Dr. Ekblaw then moved that the president cast a unanimous vote for the candidates who were nominated. Mr. Milton Thompson seconded the motion which carried.

Undergraduate Research Conference.—Dr. G. R. Thiessen, Director of the Conference, gave an interim report on the Conference which was held at the University of Illinois, Urbana, Illinois, on February 22 and 23. Dr. Ekblaw moved the acceptance of the report. Dr. Thomas seconded and the motion carried.

Dr. Ekblaw then made a motion, seconded by Dr. Thiessen, that the incoming Council be directed to continue the idea of further conferences. The motion carried.

Dr. L. J. Thomas, who served as A.A.A.S. delegate, asked the opinion of the Academy concerning the increase of dues in the A.A.A.S. and the combining of *Science* and *Scientific Monthly* into one publication. A motion by Dr. Thiessen that the delegate to the A.A.A.S. from the Illinois State Academy of Science be authorized to vote for an increase in dues carried.

Upon a motion by Dr. Ekblaw, the members attending the business meeting arose in appreciation of the work done by the officers during the past year.

The meeting adjourned at 5:55 p.m. C. D. T.

CONSTITUTION AND BY-LAWS OF THE ILLINOIS STATE ACADEMY OF SCIENCE

(Adopted May 3, 1957)

CONSTITUTION

Article I. Name

This Society shall be known as the Illinois State Academy of Science.

Article II. Objects

1. The objects of the Academy shall be the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the science interests of the state.

Article III. Membership and Dues

1. Any person of good character, proposed by two members of the Academy, and recommended by the chairman of the Membership Committee may be elected to any class of membership in the Academy by a majority vote of the Council upon payment of scheduled dues. Any organization approved by the Chairman of the Sustaining Membership Committee may become a sustaining member or a patron upon payment of appropriate dues. Individuals who attended the organization meeting of the Academy in 1908, paid dues for that year, and signed the original constitution of the Academy are designated *charter members.*

2. Individual members in good standing shall have the privilege of voting at the annual meeting, holding office, presenting papers at meetings, having such papers published if accepted by Committee on Publications, and receiving one copy each of all publications of the Academy.

3. The dues shall be as follows:

Regular member, annual	$ 2.00
Life member, single payment	$50.00
Sustaining member, annual	$10.00—$49.00
Patron, annual	$50.00 or more

4. Proceeds from life memberships shall constitute an inviolate permanent investment fund from which only the annual income may be used. Proceeds from sustaining and patron memberships shall be used to finance the activities of the Junior Academy and to advance its program as shall be determined by the Council.

5. The fiscal year of the Academy shall be from May 1 of one year through April 30 of the succeeding year. Members who fail to pay dues for any fiscal year shall be considered in arrears for that year, and unless they pay dues by the succeeding December 31 they shall be dropped from membership as of that date.

Article IV. Officers

1. A President, a First Vice-President, a Secretary, and a Treasurer shall be elected by the members of the Academy at its annual meeting, shall hold office for one year or until their successors are elected and take office, and shall perform the duties usually pertaining to their respective offices. The First Vice-President shall also assist the Secretary in formulating the program for the annual meeting.

2. If between annual meetings of the Academy the offices of both President and First Vice-President shall become vacant, the last available Past President shall act as President until the next annual meeting. Interim vacancies in the offices of Secretary and Treasurer shall be filled by pro-tem officers elected by the Council.

3. A Second Vice-President, who shall preferably be a resident of the community in which the next annual meeting is to be held, shall be elected by the Council each year and shall serve as Chairman of Local Arrangements for that meeting. When possible, a Second Vice-President Elect, who shall preferably be a resident of the community in which the second next annual meeting is to be held, shall also be elected by the Council, subject to confirming election as Second Vice-President by the next succeeding Council.

4. The Director (or Acting Director) of the State Museum Division of the Department of Registration and Education of the State of Illinois, or a member of the State Museum Staff designated by the Director to represent him on occasion of his temporary absence, shall be the Librarian of the Academy and as such shall have charge of all books, collections, and similar property of the Academy, shall serve as archivist of all official records and documents of the Academy, and shall have charge of the distribution, sale and exchange of publications of the Academy, in accordance with policies determined by the Council.

Article V. Council

1. The Council shall consist of the six officers of the Academy, the General Chairman of the Junior Academy, the Coordinator of the Collegiate Section, and three recent past officers of the Academy.

2. Except as otherwise herein provided, the members of the Council shall be elected annually by the members of the Academy at its annual meeting and interim vacancies in these positions shall be filled by pro-tem elections by the Council.

3. The Council shall manage the affairs of the Academy between annual meetings of the Academy and shall be responsible for the general planning, policies, program, and arrangements for annual meetings. It shall meet on call by the President ordinarily four times each year—once as soon as convenient after the annual meeting of the Academy, once each normally in November and February, and once just prior to the next annual meting of the Academy.

Article VI. Technical Personnel

1. A Technical Editor of the *Transactions* recommended by the Committee on Publications shall be elected each year by the Council. The editor shall be responsible for all the technical preparation of the material to be published in the *Transactions* and for all technical details connected with its composition and issue, in accordance with policies and principles determined by the Committee on Publications and approved by the Council.

2. A Publicity Adviser shall be elected each year by the Council and he shall be responsible for appropriate publicity concerning all meetings and affairs of the Academy.

Article VII. Meetings of the Academy

1. The regular annual meeting of the Academy shall be held at such time and place as the Council may designate. Meeting places shall be determined at least two years in advance.

2. Special meetings of the Academy shall be called by the President upon written request by twenty members.

3. No meeting of the Academy shall be held without thirty days previous written notice by the Secretary to all members.

Article VIII. Junior Academy

1. In order to foster science among youth, the Academy is committed to sponsorship of an organization of junior high-school and high-school students interested in science and directed by qualified teachers in the schools of Illinois, which organization is termed the Junior Academy.

2. The affairs of the Junior Academy shall be conducted in accordance with policies and principles determined by the Council of the Academy.

3. The directing head of the Junior Academy shall be a General Chairman who shall be elected by the members of the Academy at its annual meeting. A General Chairman Elect shall also be so elected. If between annual meetings the position of General Chairman becomes vacant, the General Chairman Elect shall assume the position, and in this event or if for any other reason the position of General Chairman Elect becomes vacant, it shall be filled by protem election by the Council.

4. No expenditures may be made and no bills or other liabilities may be incurred on behalf of the Junior Academy without prior approval of the Council.

Article IX. Publications

1. The regular publication of the Academy shall be the *Transactions of the Illinois State Academy of Science* and shall be published annually.

2. Other publications may be authorized by the Council.

3. All individual members in good standing are entitled (1) to have published in the *Transactions* any paper which they present at the annual meeting of the Academy and which is accepted for publication by the Committee on Publications and (2) to receive one copy of the current issue of the *Transactions*. No member in arrears shall receive the *Transactions* for any year

for which he is or remains in arrears.

4. Papers presented at annual meetings of the Academy by non-members at the invitation or with the approval of the Council shall be eligible also for publication by the Academy.

Article X. Business and Finance

1. Life membership payments shall constitute an inviolate endowment fund which shall be invested in guaranteed securities and of which only the income, in lieu of annual dues of the life members, shall be used by the Academy.

2. A second investment fund consisting of donations, bequests not otherwise restricted, allotments transferred by the Council from surplus reserve in the treasury, and similar sources shall be maintained as an emergency reserve, and only the income from this fund shall normally be available for the expenses of the Academy.

3. No expenditures may be made and no bills or other liabilities may be incurred by any officer, individual, or committee on behalf of the Academy, unless they are included in the budget, without prior approval of the Council.

4. At its first meeting each Council shall approve a budget of expenditures that shall not exceed the total of the current balance and the anticipated receipts, which budget may be modified by the Council at its subsequent meetings. The Treasurer shall not make payments for approved expenditures in excess of the covering item in the approved budget without express approval of the President and the Secretary. Such excesses must be covered by modifications of the budget at the next Council meeting.

5. The Secretary and the Technical Editor shall each receive an honorarium in amounts to be determined by the Council. These honoraria shall be paid by the Treasurer annually in March.

6. The Secretary and the Treasurer shall be reimbursed for their expenses while attending Council meetings and annual meetings. Other members of the Council may be reimbursed for their expenses while attending Council meetings other than those held in connection with annual meetings.

Article XI. Affiliations

The Academy may enter into such relations of affiliation with other organizations of appropriate character as may be recommended by the Council and approved by the members of the Academy at its annual meeting.

Article XII. Amendments

Proposed amendments to this constitution shall become effective upon approval by three-fourths of the members present and voting at the annual business meeting of the Academy, provided that notice of the proposed changes has been sent by the Secretary to all members of the Academy at least twenty days before such meeting.

BY-LAWS

I. Order of Business

1. The business meetings of the Academy and the meetings of the Council shall be conducted in accordance with Robert's Rules of Order.

2. Fifteen members shall constitute a quorum of the Academy and six Councillors shall constitute a quorum of the Council.

II. Committees and Delegates

1. The standing committees of the Academy shall be Affiliations, Animal Experimentation in Research, Budget, Conservation, Conservation of Archaeological and Historical Sites, Junior Academy Advisory and Scholarship, Legislation and Finance, Living Memorials, Local Conventions, Membership, Publications. Research Grants, Science Talent, Sustaining Memberships, State Museum Building, and Teacher Training. Any of these committees may be abolished and additional ones may be established upon recommendation of the Council at any annual meeting of the Academy.

2. Except for the Committee on Publications, the chairmen and members of the standing committees shall be elected by the members of the Academy at its annual meeting. Interim vacancies on the committees shall be filled by the Council, who shall have authority also to elect additional members.

3. The Local Conventions Committee shall consist of the last three available Second Vice-Presidents, the Secretary of the Academy *ex-officio*, and a representative of the Junior Academy.

4. The Committee on Publications shall consist of six members representing various Sections of the Academy and elected by the Council at its first meeting, two each year for terms of three years. Interim vacancies shall be filled

by members elected by the Council to complete the unexpired terms.

5. There shall be also Committees on Audit, Nominations, and Resolutions of which the members shall be appointed by the President not later than the February Council meeting.

6. The duties of the committees shall be as defined by the Council, except as hereafter provided.

7. The Budget Committee shall submit at the last Council meeting for its consideration and for review at the annual meeting of the Academy a budget of anticipated income and recommended expenditures for the following year. The budget shall be approved by the succeeding Council at its first meeting.

8. The Junior Academy Advisory and Scholarship Committee shall supervise the management of the affairs of the Junior Academy in accordance with policies and principles determined by the Council.

9. The Local Conventions Committee shall prepare and maintain up-to-date a "hand book" for the guidance of Second Vice-Presidents in discharging their duties as Chairmen of Local Arrangements and shall further advise such officers when requested.

10. The Committee on Publications shall be responsible for the editing of the *Transactions* and of any other publications authorized by the Academy or Council. It shall establish editorial policy, shall review papers submitted for publication and determine which are acceptable, and shall submit to the Council the names of one or more candidates for election as Technical Editor. Sometime between May 1 and September 1 of even-numbered years the Chairman and/or other members of the Committee shall confer with the Director of the Illinois State Museum concerning the amount of appropriations that should be requested for publication of the *Transactions* during the next State biennium.

11. The membership of the Audit, Nominations, and Resolutions committees shall be announced to the members of the Academy by the President or the Secretary not less than thirty days prior to the annual meeting.

12. The Nominations Committee shall present at the annual business meeting of the Academy a list of candidates for all offices and committees which shall be filled by election by members of the Academy.

13. The Resolutions Committee shall present at the annual business meeting of the Academy all resolutions for consideration by the members of the Academy, with recommendations for or against approval. Members of the Academy who wish to sponsor resolutions shall submit them to the Resolutions Committee for consideration not less than 24 hours and preferably longer before the annual meeting. No resolution not submitted to the Committee may be presented at the meeting of the Academy. The Committee shall draft any appropriate resolutions as directed by the officers of the Academy or Council, may redraft any resolution submitted by any member or members to place it in more acceptable form, and may draft resolutions to incorporate suggestions offered by members of the Academy.

14. One or more delegates to the American Association for the Advancement of Science or to any other organization with which the Academy is affiliated, when such delegates are required, shall be elected each year by the Council.

III. Technical Sections

1. Technical papers presented at the annual meeting of the Academy will be distributed among Sections representing various fields of science as follows: Aquatic Biology; Archeology and Anthropology; Botany; Chemistry; Geography; Geology; Physics; Science Education, Psychology, and Social Science; Zoology; and Collegiate.

2. Any of these sections may be abolished, divided, or combined by the Council as seems desirable, and other sections may be established by the Council upon request of ten active members.

3. Members of the Academy shall indicate in which section or sections they are particularly interested.

4. The members present at any section meeting during the annual meeting of the Academy shall constitute a quorum of the section. They shall elect a chairman for the ensuing year, who shall be responsible for assembling a program for the section for the next meeting. In the event that an elected chairman can not serve, a substitute shall be elected by the Council.

5. The Coordinator of the Collegiate Section shall cooperate with its elected officers in conducting its affairs, subject to the advice and approval of the Council.

6. No paper shall be entitled to a place on the Section programs unless the manuscript or an abstract of the same shall have been previously delivered to the Secretary in accordance with instructions. No paper shall be presented at any Section meeting by any person other than the author, except with approval of a majority of the members present at such meeting. Manuscripts of papers intended for publication should be delivered to the Secretary at the time of the annual meeting or promptly thereafter, and in the latter case the Secretary must be notified accordingly at the time of the annual meeting. No paper shall be accepted for publication unless the author or a co-author is a member of the Academy or an approved applicant for membership or unless it has been presented at the invitation of or with the approval of the Council, nor shall any paper published wholly or in large part elsewhere be acceptable for publication.

IV. Suspension or Amendment of By-Laws

1. These by-laws may be suspended or amended at any annual meeting of the Academy by a majority vote of the members present.

PREPARATION OF MANUSCRIPTS FOR THE TRANSACTIONS

For publication in the *Transactions*, articles must present significant material that has not been published elsewhere. Review articles are excepted from this provision, as are brief quotations necessary to consider new material or varying concepts. All manuscripts must be typewritten, double spaced, with at least one-inch margins. The original copy, not the carbon copy, is to be submitted.

Titles should be brief and informative. The address or institutional connection of the author appears just below the author's name. Subtitles or center headings should be used; ordinarily one uses subtitles such as *Introduction, Acknowledgments, Materials, Methods, Results, Discussion, Summary,* and *Literature Cited.* All papers should have a summary.

No footnotes are to be used.

The section entitled *Literature Cited* must include all references mentioned in text. It is not to include any other titles. No references to the literature are to be placed in footnotes. Citations under *Literature Cited* are as shown below:

Doe, John H. 1951. The life cycle of a land snail. Conchol., 26(3): 21-32, 2 tables, 3 figs.

Doe, John H. 1951. Mineralogy of Lower Tertiary deposits. New York, McGraw-Hill Book Co., iv + 396 pp.

Quoted passages, titles, and citations must be checked and rechecked for accuracy. Citations to particular pages in text are Doe (1908:21-36) or (Doe, 1908:21-36); general citation in text is Doe (1908) or (Doe, 1908).

Tabular information should be kept at a minimum. Tables should not be more than one page in length. Do not duplicate tabular data in text. Headings for tables and columns should be brief. Reduce to the barest essentials, or preferably omit, explanatory notes on tables. Each table and its heading should be on a single page; do not place any table on the same page with text.

Photographs should be hard, glossy prints of good contrast. Graphs, maps and other figures reproduce best when prepared for at least one-half reduction; lettering, numerals, etc. on all figures in a manuscript should be worked out to proper size for such reduction. Line widths, letter size etc. should be uniform from figure to figure within a published paper. Figures should be drawn on good quality white paper or on drawing board. Use only India ink. Use a lettering device (Leroy or Wrico) for numerals and words; do not print "free-hand."

Legends for photographs and figures should be brief; type them on a separate sheet of paper. Indicate figure number and your name on back of illustration; do not write with pencil on the backs of photographs.

Authors will receive galley proofs; these should be read carefully and checked against the original manuscript. Reprints may be ordered at the time galley proofs are returned to the Editor:

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